# HARD WHITE WINTER WHEAT
# HAMBURGER BUNS AND COUSCOUS
# PRODUCT DEVELOPMENT

by

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# PREFACE

This thesis format is different from the conventional thesis style. The "Experimental" section includes two manuscripts based on experimental work that are complete within themselves containing Abstract, Introduction, Materials and Methods, and Results and Discussion. The "Summary and Conclusions" follow summarizing the entire research as a whole. A comprehensive "Literature Cited" is the final section of this thesis.

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# INTRODUCTION

Hard red winter (HRW) is the major wheat class produced in the United States (54% of the total 1984 wheat crop grown in the U.S.)(Siegenthaler et al 1986). Figure 1 shows the U.S. HRW wheat cultivated area (Anon. 1981). Of the total crop in 1984, red wheats accounted for eighty eight percent and white wheat (most of these being soft) twelve percent (Siegenthaler et al 1986). Figure 2 shows the White Wheat cultivated are in the U.S. (Anon. 1981). Of the thousands of genes in every cell of a wheat plant, only three determine kernel color. If none of the three genes are for red, the wheat bran is white, yet the rest of the characteristics of the wheat plant are the same as in its red wheat sister line (Graham 1988).

# LITERATURE REVIEW

## HARD WHITE WINTER WHEAT HISTORY IN THE UNITED STATES

The United States is largely a nation of immigrants with respect to its population and entirely so with respect to present wheat varieties. In the U.S., wheat production began along the Atlantic coast in the early 1600's and moved westward. Most early varieties appear to have been soft winter wheats; white grains were preferred to red because red discolored the flour. As wheat production spread west into the prairies, the soft eastern varieties did not prove to be well adapted to the increasingly dry lands. There was

Fig. 1 HRW Wheat Cultivated Area in the United States

Fig. 2 White Wheat Cultivated Area in the United States

a need for drought-resisting varieties. These were initially provided through hard wheat introduction. In the early 1870's, a HRW wheat known as Turkey was introduced into Kansas by Mennonite settlers from Russia. For many years, Turkey wheat was the most important variety grown in the United States. A Turkey descendant, Turkey Red was the main source for later dwarf varieties (Dalrymple 1980). Turkey wheat provided the initial germ plasm for HRW production on the U.S. plains (Reitz 1976). Today, HRW is seeded on more acres in the U.S. than all other classes combined.

The original white wheats raised in the United States were soft, but in the early 1900's two hard varieties from Australia were introduced (Dalrymple 1980). Work on breeding hard white winter (HWW) wheat began in the 1950's, but not much emphasis was placed on it until recently (Feltner 1988). The main difference between HRW and HWW are color and taste. These two wheats are fairly close substitutes for baking purposes; this is not the case for hard wheat flour and soft wheat flour (Babcock 1989).

In recent years, interest in HWW has accelerated due to its potential as an alternative crop or specialty crop that would require little in the way of new technology or machinery (Feltner 1989). Many world markets prefer HWW from Australia to HRW from the U.S. for use in noodles or flat breads. The U.S. has not had any HWW with which to compete against Australia (Graham 1988). Six states now

have active breeding programs to produce HWW and two states are producing them commercially. California leads with the commercial production HWW. This production has increased to the extent that export shipments are predicted for 1989 (Federal Register 1989). The California Wheat Commission is promoting its HWW variety for export, and thus competing with Australia (Anon. 1988). Kansas wheat producers are growing two HWW varieties which are identity-preserved in the marketing system (Federal Register 1989). Kansas is most interested in developing a white bread wheat for domestic use (Anon. 1988). Montana State University is working on several varieties. Colorado and Idaho are producing HWW in small quantities from the California variety (Federal Register 1989).

HRW wheat is the major class produced in the U.S., but many countries prefer white wheat. HWW wheat is as agronomically feasible as HRW wheat in the major U.S. wheat area. Both classes are equally suitable for breadmaking, and preharvest sprouting is not a barrier to white wheat production most years. White wheat production in the U.S. could be increased in the Great Plains HRW area. Milled flour protein concentrations differed more among location than between red and white wheats. Loaf volume differed inconsistently between the two wheats (Paulsen et al 1983). HWW wheats that are equivalent and in some ways superior to red wheat seem feasible. The best experimental wheat lines

plant and grain yield characteristics were similar to those of the most popular hard red winter wheats. There apparently is no agronomic barrier to high yields and quality hard white wheat grain in the U.S. (Upadhyay et al 1984). The moderate sprouting resistance level in the Kansas experimental white wheat lines would be adequate for the U.S. HRW wheat region (Upadhyay et al 1984).

AUSTRALIAN HARD WHITE WHEAT

Australia, as a wheat producing nation, is unique in that it traditionally produces only white-grained wheat and exports a large proportion of its annual crop (Mares 1987). In Australia, white-grained wheats of spring habitat are grown over the mild winter months and harvested during the summer months. Historically the Australian wheat classification system has been very conservative in the allowance of sprouted wheat into milling grades. The major class of Australian wheat, Australian Standard White (ASW) has a nil tolerance to visibly sprouted grain. For many years, the only class in which sprouted wheat could be delivered was General Purpose. This rather conservative approach has resulted in Australian milling wheats gaining an international reputation for soundness (McMaster 1987). A comparison of Australian and U.S. Wheat Classification are listed in Table I.

Before farmers can deliver wheat into the bulk handling system, the wheat must conform to strict receival standards.

TABLE I

AUSTRALIAN AND U.S. WHEAT CLASSIFICATION

| Australian Wheat Classes[1] | U.S. Wheat Classes[2] |
|---|---|
| Durum | Durum Wheat |
| Prime Hard | Hard Red Spring |
| Hard | Hard Red Winter |
| Soft | Soft Red Winter |
| Standard White (ASW) | White |
| General Purpose | Unclassed |
| Feed | Mixed Wheat |

[1]McMaster, 1987

[2]Federal Register, 1989

These standards are set by the Australian Wheat Board (AWB). All wheat which conforms to AWB's basic receival standard for ASW wheat is considered to be suitable for milling. Australian wheat is marketed in a number of general classes on the basis of protein content, grain hardness, dough properties and milling quality. Australian Prime Hard is limited to high-quality, especially-selected, hard-grained varieties renowned for their milling quality and balanced dough properties; it is guaranteed 13% minimum protein. Australian Hard consists of selected hard varieties of proven bread-making quality; guaranteed minimum protein 11.5%. Australian Standard White is a multipurpose wheat of intermediate grain hardness with a protein level in the 9.5 to 11.5% range. Australian Soft consists of low protein, soft wheat. Australian Durum consists of hard grained durum varieties. Australian General Purpose wheats are those failing to meet the strict ASW receival standards for either test weight screening or foreign material, excessive weed seeds or mild sprouting. Australian Feed comprises wheat which has serious defects which include severe sprouting, excessive unmillable material and/or foreign material, and low test weight. This wheat is suitable only for stock feed purposes (Anon. 198?). Australians divide their wheat into five grades (Prime Hard, Commercial Hard, Fair Average Quality, Commercial Soft, and Off Grade). The Off Grade Wheat is wheat that, due to

environmental factors such as sprouting, is graded separately. These grades are subdivided according to shipment point. Figure 3 shows the areas from which the various wheat grades are obtained (Moss 1973). To Australians, wheat is so important they have put it on their two dollar bills.

## THE SPROUTING PROBLEM

In the U.S., interest in HWW has increased significantly in recent years following a recognition of some of its advantages, in particular milling quality, over red wheat in the international marketplace. Until recently it was generally accepted that white-grained cultivars were all susceptible to pre-harvest sprouting and that this represented a considerable constraint to their successful cultivation in many wheat growing regions of the world (Mares 1987). Wheat with white kernel color has traditionally been considered to have a short dormancy period and therefore to be susceptible to sprouting. Susceptibility to preharvest sprouting is a major disadvantage of HWW wheats as compared with most HRW wheat cultivars in the U.S. plains. More attention to the preharvest sprouting problem may be needed for HWW production than is now needed for HRW (Nielsen et al 1984). Recent research has provided evidence that there are exceptions to this generalized relationship (Depauw and McCaig 1987). Clark's Cream (HWW) was significatly

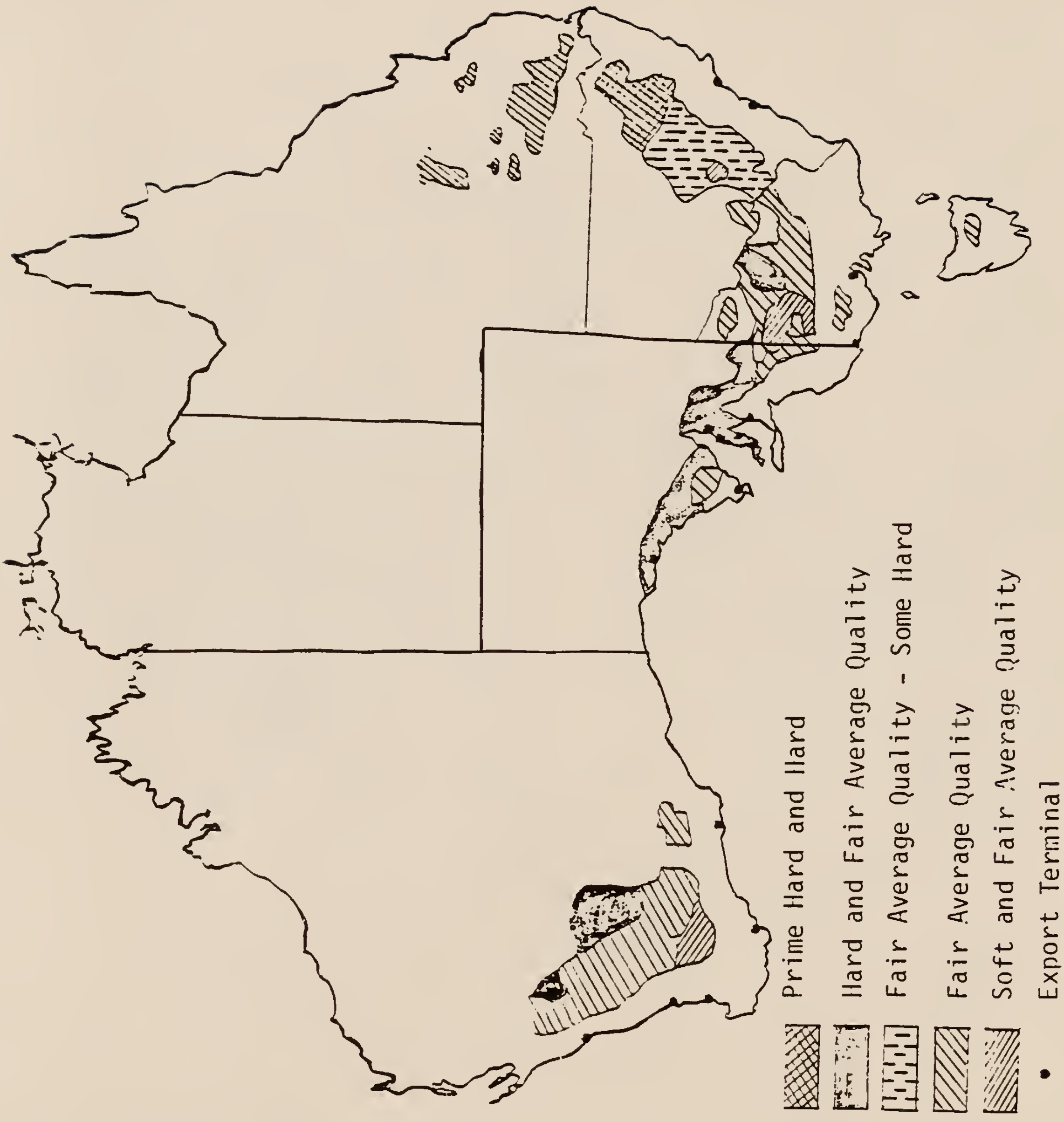


Fig. 3 Australian Wheat Crop Distribution According to Grade

different with respect to sprout damage than other HWW (Huang 1979). Consequently the increased interest in white wheats has been paralleled by the establishment of research programs at several centers throughout Canada and U.S. aimed at improving sprouting tolerance (Mares 1987). Preharvest sprouting resistance is a major breeding factor in many regions where white wheat is produced. Present results indicate that incorporating resistance to preharvest sprouting into desirable wheat is an attainable goal. When a wheat is found to be resistant to sprouting it can be passed to other wheats (Upadhyay and Paulsen 1988, & Morris and Paulsen 1987). Resistance to preharvest sprouting has been observed in several white wheat genotypes, but the resistance mode has not been determined. Knowing the sprouting resistance mechanism would greatly aid breeding for the trait (Upadhyay et al 1988). Similar programs have been in progress for many years in Australia (Mares 1987).

Australian wheat is normally harvested in excellent condition with a very low alpha-amylase activity. Excessive alpha-amylase activity is rarely a problem with Australian flour. When adverse conditions are experienced at harvest, the cultivars commonly deteriorate more rapidly than do Canadian red wheats with respect to alpha-amylase activity. It seems that tolerance to pre-harvest rain damage has not been detected among the Australian white wheats examined. The extent of weather damage depends largely on the rainfall

and the temperatures experienced, and on the stage of maturity of the plants when the damage actually occurs (Moss et al 1972). The majority of Australian wheats remain susceptible to sprouting (McMasters 1987). New South Wales in Australia commonly receives heavy rains when the wheat crop is mature. The high temperatures combined with warm winds facilitate the rapid crop redrying. Therefore, the resistance levels required are somewhat less than those necessary in some other parts of the world. This situation is fortunate for Australians who traditionally cultivate white-grained wheats (Mares 1983).

Wheat grain sprouting resistance is closely related to pericarp color (McCrate et al 1981). New sources of tolerance to pre-harvest sprouting have been identified which have the potential to dramatically improve HWW tolerance (Mares 1987). Increased sprouting resistance incorporation into modern white wheat would be desirable both in fringe areas where sprouting may be troublesome and when the harvest is delayed by adverse weather conditions. In the HRW growing area, HWW is better suited for western Kansas where there is less chance of rain before or during the harvesting season (Lytle 1989).

Wheat preharvest field sprouting reduces a flour's baking potential because wheat alpha-amylase and protease concentrations increase. Baking experiments with flours milled from wheats with varied degrees of spouting

demonstrated that excessive alpha-amylase causes dough stickiness and poor handling and machining properties in white pan bread (Lorenz et al 1983, & Morris and Paulsen 1988). A reduction in pan bread quality may also be observed if sprouting damage is present in wheat. Sticky crumb, excessive crust color and reduced loaf volume are evident in these breads, and slicing problems may arise in the modern automated bakery. The greatest tolerance to sprout damaged flour is exhibited by end-products similar to those in the Indian sub-continent (eg. chapattis and rotis). Their color, flavor and texture characteristics are still acceptable when prepared with flour milled from wheat containing low levels of sprouted grain (McMaster 1987). In a study of nine international breads (five yeast-fermented and four unfermented breads), seven (Egyptian bread, Moroccan Sour-dough & Straight dough whole wheat bread, Indian Breads: Chapatti, Puri, Paratta, & Naan) were judged suitable even when produced with highly sprouted wheat flour. Those seven were considered equal to breads produced from sound wheat flour (Finney et al 1980).

Some end-products are affected more than others when flour is milled from wheat containing sprouted grain. The most sensitive end-products made from sprouted wheat flour are various types of oriental noodles. In fact, small levels of weather damage can result in major defects of these end-products. Approximately one third of Australian

wheat exports are used for noodles; it is very important to accurately segregate sound from unsound wheat for these markets (McMaster 1987).

HWW WHEAT ADVANTAGES

Potential customer preference for HWW is motivated by several perceived advantages.

1) White wheat flour at high extraction levels appears to have a much lighter color than conventional flour.

2) Wheat flours contain more protein when the kernel is milled to a higher extraction than when milled at normal extraction rates. This protein is nutritious, but not functional for bread making.

3) Whole-wheat products may appear more appealing to many consumers when the flour is milled from hard white wheat.

4) Bran from HWW is potentially more valuable than bran from HRW. Red bran is usually considered to be a feed by-product of the milling process. White bran is used in many high fiber foods, particularly breakfast cereals and snacks. The short supply of white bran for these uses boosts its price to the extent that it is considered a valuable co-product, and not a by-product, of the milling process. Also, white bran might be used instead of other materials to increase the fiber content of many baked products, such as high-fiber bread, while still maintaining the preferred lighter product color (Paulsen et al 1983).

5) HWW has a less astringent flavor than does HRW (Feltner 1988).

6) Higher flour extraction rates are possible (1-3%) with HWW than with HRW when both are milled to similar color standards. Milling standards based on color specifications have been or are being adopted by several countries (Feltner 1989).

7) White wheats are preferred for many export markets. Thus, a quality HWW almost certainly would enhance export potential (Watson 1987). Traditionally, noodles in South-East Asia have been made from Australian wheat. The preference is due to white wheat which gives the product a good color. The grain from Australia is clean, sound and dry (Moss 1983).

The advantages attributed to white wheats suggest that tradition, more than agronomic and baking characteristics, accounts for the HRW dominance in the U.S. wheat growing region (Paulsen et al 1983).

HWW WHEAT CLASSIFICATION

The U. S. Standards for Wheat include seven classes (Federal Register 1989) (Table I). There is no classification for true HWW in the current U.S. Grain Standards. Presently, the white wheat class includes hard white, soft white, western white, and white club. Most of the white wheat is soft and used for bakery products other than bread, or for breakfast cereals. However, hard wheats

are primarily for bread making (Feltner 1989). Some current U.S. soft white wheats may appear to be hard, but still have the functional milling and flour properties of soft wheat, and are not therefore suitable for most hard wheat applications (Bequette 1989). Visual wheat examination to determine class and subclass has been used since 1917 and is currently the only approved method. The visual wheat analysis for vitreousness does not indicate whether the endosperm is hard or soft (Federal Register 1989).

HWW classification will only be accomplished after three issues are addressed by the Federal Grain Inspection Service (FGIS):

1. FGIS white wheat classification system
2. FGIS hardness testing procedures
3. Kernel color determination (Bequette 1989)

The FGIS is responsible for evaluating new inspection techniques and proposing changes in grain standards. Before FGIS can establish, amend or revoke any of its standards, it is required by law to publish an announcement in the Federal Register, the federal government's legal newspaper. After publication, a time period is allowed for interested persons to submit their arguments. It may take from 9 months to several years to change the standards (Fulk 1988).

White Wheat Classification

The recent development of HWW creates a need to revise the U. S. Standards for Wheat. Milling and baking studies

demonstrate a significant difference in milling properties and in end-use functions between hard and soft white wheats (Federal Register 1989).

There have been problems with the U.S. wheat classification system ever since it began in 1917. In order to get data for an overview of problems in classing wheat, FGIS collected wheat samples from several inspection points in 1987. All samples were evaluated for single kernel hardness, protein, moisture, and official FGIS grade. It is hoped that information gathered will provide cut-off points and class limits between hard and soft wheats. Adoption of a realistic, flexible, and long-term classification system which will predict potential end-use for the hard and soft classes is highly desirable, and would benefit all concerned (Mattern 1988a).

The current grading system does not properly identify white wheat. Hard and soft white winter wheat may look the same and be graded the same, but they are different types. By current U.S. Grain Standards, the white wheat class is divided into hard and soft subclasses. If a sample of wheat has less than 75% vitreous (translucent in appearance), non-chalky kernels, it is classified as a soft white wheat. Samples with 75% or more vitreous kernels are classed as a hard white wheat by a visual appearance. Many soft white wheats will be graded hard, and hard white wheat which should be used for bread will be graded soft white (Lytle

1989). Traditionally, vitreousness has been associated with hardness and chalky kelnels with softness, but vitreousness and hardness do not result from the same cause. In tightly packed kernels, with no air space, light is diffracted at the air-grain interface but then travels through the grain without being diffracted again and again. The result is a vitreous appearing kernel (Hoseney 1986). The subclass hard white was originally established to identify soft white wheat which had a high percentage of vitreous kernels, and were suitable for special purposes such as puffed breakfast cereal (Bequette 1989). When wheat is conditioned and milled, hard and soft wheats are easily distinguished because they don't mill the same, and the flour is not the same (Lytle 1989). Soft wheat breaks up easier in the milling process and produces more flour in the break rolls. It also produces a flour with a smaller particle size and less damaged starch. The FGIS is proposing to amend the U. S. Standards for wheat by replacing the single class White Wheat with two classes: Hard White Wheat (HWW) and Soft White wheat (SWW). The SWW class would have three subclasses: Common White, White Club and Western White (Federal Register 1989). The lack of a market classification for HWW is a marketing obstacle and creates a problem in seed availability for planting. It could easily be five years before hard white is in general release for use by the average farmer (Lytle 1989).

Substantial wheat quantities produced in Northwest Kansas, the Nebraska Panhandle and Colorado are now exported from Portland, Oregon. If hard white wheat becomes a significant crop in Kansas, Nebraska, or Colorado, there will be opportunities for accidental or intentional hard white and soft white mixing at Portland terminals (Bequette 1989). Introduction of a new wheat class must recognize the established class tradition and the adjustments that must be made by the grain trade (Upadhyay 1984).

Hardness Testing

Knowing wheat hardness is important due to its influence on a product's quality. In marketing channels, wheat hardness is judged by appearance rather than by an objective test (Miller et al 1982). There is a need for a rapid, objective means to determine wheat hardness to classify wheat according to its end-use functionality. Reliable single kernel and bulk hardness tests will be essential if Hard White wheat is grown in areas where Soft White wheat is produced, or if Hard White is moved through an area where Soft White is produced or marketed (Bequette 1989). Several bulk sampling methods have been tested for wheat hardness evaluation. Near-infrared analysis (Williams and Sobering 1986b), measurements of the ease of grinding (Williams et al 1987), the particle size index (PSI) method (Williams 1979; Williams and Sobering 1986a), and pearling resistance (Chesterfield 1971) are all means of determining bulk sample

hardness properties. Although these methods are suitable when homogeneous wheat lots are tested, they are not discriminating enough for identifying hard and soft wheat mixtures (Eckhoff et al 1988). Today, many methods are available to wheat breeders, millers and cereal technologists to determine hardness. Only pearling and PSI seem to have found wide acceptance in routine wheat hardness testing (Bequette 1973).

Hardness tests based on crushing or indentation involve measurements on single grains (Simmonds 1974). A method using a continuous, automated single-kernel hardness test has been used to test hardness by recording the stress-strain relationship encountered when crushing kernels (Lai et al 1985). Individual wheat kernels have been crushed and then viewed through a microscope to classify them on a hardness scale from 1 to 10 (Mattern 1988b). This method, though a subjective one, appears to be the most accurate one available and will be used as a standard for individual kernel test, but it is labor intensive and time-consuming.

The FGIS desires a single-kernel wheat hardness test at a rate of 400 kernels per 5 min. This rate and sample size would correspond to the FGIS current visual classification procedure. An instrument developed at Kansas State Univiversity was designed to be rapid enough for FGIS inspection requirements and to compensate for kernel factors affecting the hardness test. The sampling rate is 200

kernels per min. Hardness evaluation is achieved by shearing individual kernels and recording the associated force breakage curves (Eckhoff et al 1988).

It seems reasonable for Hard White breeders to discard lines which have hardness values below the average for HRW varieties. A narrow hardness range within and a large difference between varieties will be important in all wheat classes when FGIS implements hardness testing as a part of wheat classification (Bequette 1989).

Kernel Color

Growing conditions, weathering, disease and other factors influence bran color. Breeders must select white wheats which are truly white. Objective methods are needed to permit the class assignment for an unknown wheat seed sample, and a procedure that would quickly distinguish a red wheat from a non-red one would be useful. A color test employing sodium hydroxide was investigated as a method for distinguishing red wheats from white common, white club, and amber durum cultivars. A modified procedure was developed which required only 5 minutes and could be performed on a single kernel. Using the modified procedure, an untrained observer could correctly classify as red or non-red all 875 samples examined (Lamkin and Miller 1980). However, if a staining test is needed to show that a line is white (or red), then it does not have a distinct color and may cause marketing problems (Bequette 1989).

Marketing HWW on an identity-preserved basis would help bring premiums to producers. Even without direct premiums, HWW would be more competitive on the world market and has the potential to be sold when HRW may not sell (Feltner 1989).

HWW WHEAT END-USE RESEARCH

A laboratory milling technique was developed to obtain 74, 76, 78, 80, and 82% flour yield with the objective of producing flours representative of those milled commercially. The new laboratory milling technique was used to evaluate the milling quality of HWW. At any given extraction level, HWW flours ash contents were only slightly lower than the HRW flours, but color scores for the HWW flours were significantly higher than the HRW control flours. This indicates that HWW wheats have a distinct advantage over HRW when milling to a flour color specification (Li and Posner 1989).

An experimental farina procedure was also developed, and HWW and HRW wheats with similar protein contents were tested by this procedure. HWW yielded 45% farina, and HRW 40%. This difference was because the HWW had larger kernels. Both wheats produced 28% left-over flour which was suitable for baking, and the HWW farina produced better spaghetti than HRW, but neither was as good as spaghetti made from durum semolina (El Bouziri and Posner 1989).

It was reported that a HWW and HRW were purified to 30% and 15% farina respectively with a speck count of 30 specks/10in$^2$. Farina from HWW made spaghetti contained up to 80% more yellow pigment than HRW farina, but the spaghetti cooking quality was the same (Kim et al 1989).

Oriental noodles were made with straight grade flour and bran fiber additions. When bran was added to the noodle formula, the noodles' color changed from creamy white to dull yellow or brownish yellow, and their breaking stress decreased. Dry noodles made from HWW high-fiber bran flour showed better color and higher breaking stress than those from HRW high-fiber bran flour. Taste panel results showed than high-fiber bran made from HWW coarse bran can be added to straight-grade flour up to 10% without noticeable taste and texture deterioration (Rho and Seib 1989).

Wheat flour from Australia (ASW & Australian Hard White, AHW), Washington (Western white(WWW), a mixture of soft white:Club=9:1), and Kansas (HWW & HRW) wheats were examined for their noodle making properties. Cooked noodles made from HWW, ASW, and WWW straight-grade flours showed good surface firmness and creamy white color. When the dry noodles were cooked, they all gave chewy noodles with a smooth slippery surface except AHW and HRW. Instant fried noodles made from HWW and ASW wheat flours resulted in acceptable textural characteristics and bright creamy color. Cooking loss was the least in HRW and the highest in ASW

(Rho and Seib 1989). A snack noodle was developed from Kansas HRW and HWW wheats. Fried snack noodles made from HRW straight-grade flour gave a harder texture than those from HWW. HWW high-fiber bran snack noodles gave a softer texture and a favorable nutty flavor compared to snack noodles made from straight-grade flour. Adding fiber did not noticeably change noodle color (Rho and Seib 1989).

Research on HWW wheat in U.S. style baked foods or other products except for those mentioned above was not found. This researcher's objective was to develop hamburger buns and couscous incorporating HWW.

# EXPERIMENTAL

HARD WHITE WHEAT

HAMBURGER BUN DEVELOPMENT

ABSTRACT

Hamburger buns account for a large percentage of wheat flour consumption. With the increased interest in high fiber foods, a whole white wheat bun which is lighter in color and more bland in flavor but has the same volume and texture than one from whole hard red wheat, might have a wide consumer acceptability. However, tests showed that as the proportion of whole wheat increased, the volume decreased. Vital gluten was used to restore the volume. White bran, as well as cracked and flaked wheats, were added to create the effect of whole wheat without seriously affecting the color. White cracked wheat, flaked wheat, bran, and whole wheat gave the buns a pleasing texture and appearance without the coarseness, bitter aftertaste, and dark color characteristic of bread made from whole HRW flours. Up to 30% cracked wheat, 40% flaked wheat, or 20% bran could be added to the formula while control height was retained by adding vital gluten. Comparing the red wheat and the white wheat buns, the Agtron gave higher values for the white ones (indicating a lighter color) except with cracked wheat, where the values were equal. In a triangle test under red light, taste panelists easily differentiated red-wheat from white-wheat buns.

# INTRODUCTION

During recent years, the American public has become more concerned with health and nutrition. This interest has resulted in an increase in the consumption of dietary fiber, and thus, high-fiber breads are being increasingly accepted by the public (Mrdeza 1978). Whole wheat bread per capita consumption increased from 3.7 pounds per person in 1972 to 9.5 pound in 1988 (Babcock 1989). Many researchers have studied the effects of fiber on bread quality (Volpe and Lehmann 1977, Becker et al 1986, Chen et al 1988, D'Appolonia and Youngs 1978, Dubois 1978, Pomeranz et al 1977, Shogren et al 1981, and Sosulski and Wu 1988). None of the fibers evaluated was from hard white wheat bran, none was ideally suited for breadmaking, and all affected some functional properties of the dough. The production of high-fiber bread in a commercial bakery is made more difficult because of weakness of the dough, blisters, holes under the top crust, and cripples. Also, optimized water absorption and mixing time are critical. The challenge is to produce, by conventional and available technology, a reasonably inexpensive, high-fiber bread that will meet with consumer acceptance (Pomeranz 1977).

When fiber is added, there is a decrease in volume that may be due to the dilution of gluten or to the interaction between gluten and fiber material (Chen et al 1988). The volume problem may be largely solved by adding vital wheat

gluten, but this causes a substantial increase in cost. It is necessary to use vital wheat gluten because of the strain put on the natural gluten by the fibrous material (Pomeranz 1977). If more than 7 to 10% fiber is added to the formula, additional vital wheat gluten is needed to maintain a quality product (Dubois 1978). Addition of sodium stearoyl-2-lactylate (SSL) in the formula also improved the loaf volume and overall bread quality of breads baked with different levels of wheat bran (D'Appolonia and Youngs 1978).

According to the National Restaurant Association, 5.2 billion hamburgers were sold in 1987. America's appetite for hamburgers is far from saturated. This market is tough, but there are still opportunities for new ideas (Kochak 1988), such as whole-wheat hamburger buns. Fresh Start Bakery (a bakery that produces exclusively hamburger buns for McDonald's) has opened four new plants in the last five years which have the capacity to produce 3,000 dozen hamburger buns per hour (Anon. 1989). Ten years ago, few restaurants offered wheat rolls; today, however, about one in every four restaurant-goers prefers a wheat roll with his or her meal (Pacyniak 1987).

Hamburger buns are made from formulas resembling those for conventional white bread, except for higher concentrations of sweetener and shortening. Bun doughs may be prepared by any of the conventional procedures, although

liquid ferment systems and continuous mixing processes appear to be generally preferred (Trum 1971). The objective of this project was to develop a high fiber hamburger bun using hard white wheat.

# MATERIALS AND METHODS

## Wheats

A commercial HRW wheat mill mix-858 (Cargill, Wichita, KS) at 13.1% protein and a HWW wheat-853 (W81-162 from 1987 NAPB flood-irrigated fields in the Fort Morgan, CO area) at 12.8% protein were processed in three different ways: cracked, flaked, and milled to flour in the Kansas State University pilot mill.

Fiber was incorporated into hamburger buns in four ways: as cracked wheat, flaked wheat, bran, and whole wheat flour. The cracked wheat was made by breaking the wheat kernels into two or three pieces with Lepage rolls. The broken kernels were then sieved, and the products thru the 8w over the 14w were used. Flaked wheat was made by tempering the wheat to 18% moisture and passing it through smooth rolls with a 0.015 in. gap to flatten the kernels. The kernels were not heated. The entire material was used; nothing was sifted out. Bran was incorporated as whole flakes, about two to five millimeters in size. The whole wheat was a proportional recombination of all the mill streams, with the bran ground in a Fitz Mill (Fitzpatrick & Co., Elmhurst, Illinois) through a screen size 0.033 inches.

## Formula

A control hamburger bun formula was developed using the liquid ferment method (Table II). The ingredients used were: Cargill Hard Wheat Bread Flour (12.6% protein on a 14%

TABLE II

CONTROL HAMBURGER BUN FORMULA

| Ingredients | Percent |
|---|---|
| Bread Flour | 100% |
| Water | 58 |
| Granulated Sugar | 12 |
| Emulsified Shortening | 10 |
| Instant Active Dry Yeast | 3.5 |
| Salt | 2.0 |
| Sodium Stearoyl 2-Lactylate (SSL) | 0.5 |
| Arkady Yeast Food | 0.5 |
| Calcium Propionate | 0.25 |
| Potassium Bromate | 40ppm |

moisture basis), Richtex Emulsified Shortening, Saf-instant active dry yeast, and ADM Arkady Yeast Food.

The liquid brew included 40% water, 7% sugar, 0.5% salt, and 3.5% instant dry yeast. All ingredients were on a flour weight basis, including the other materials added later. The mixture was fermented for 1 1/2 hours with slow stirring. It was then cooled to 10 degrees Celsius in an ice bath. The dry ingredients, except for the salt, were mixed for 15 seconds in a 200g Pin Mixer (National Manufacturing Co. Lincoln, NE). The shortening, brew, and the free water were added, and mixed for 2 1/2 minutes. The salt then was added, and the dough was mixed 1 more minute. The dough was formed into a ball, let rest five minutes, and divided into six 60 g pieces that were rounded by hand. The pieces were sheeted through an ACME Bench Dough Roller (McClain & Sons, Pico Rivera, CA). The first roller was at setting 4 (1.0 cm) and the second at setting 1 1/2 (0.6 cm). The flattened dough pieces were then placed in 10 cm diameter cups of greased hamburger bun pans. They were proofed for 50 minutes at 105°F (40 C) dry bulb and 100°F (38 C) wet bulb (85% relative humidity), and then baked six minutes at 225°C. The buns were bagged after cooling for one hour at room temperature.

**Cracked Wheat Addition**

Cracked wheat was added to the control formula at 10, 20, 30, and 40%. These quantities and those used for flaked

wheat, bran, and whole wheat were determined from preliminary experiments and the literature on fiber additions to loaf bread. Vital gluten was added at 5, 10, 15, and 20%, on a flour weight basis. For every 1% cracked wheat added, 0.2% percent of water was added, as determined by prior experiments.

For all the formulations, absorption was increased 1% for every 1% of vital gluten added, and the mixing time was increased by 1/2 minute for every 5% increase in vital gluten.

**Flaked Wheat Addition**

Flaked wheat was added to the control formula at 10, 20, 30 and 40%, and vital gluten was added at 5, 10, 15, and 20%. Absorption was increased by 0.4% for every 1% of flaked wheat added.

**Bran Addition**

Bran was added to the control formula at 5, 10, 15, and 20%, and vital gluten was added at 5, 10, 15, and 20%. There was a 1% absorption increase for every 1% of bran added.

**Whole Wheat Replacement**

Whole wheat replaced bread flour in the control formula by 20, 40, 60, and 80%, and vital gluten was added at 5, 10, 15, and 20%. There was a 1% absorption increase for every 10% whole wheat replacement.

**Measurements**

After 24 hours, the bun height in centimeters was measured with a caliper. This method was compared to seed displacement, and bun template measurements; height measurement was found to be the most rapid method and had a good correlation ($R>0.9$) to the other methods (data not shown). The best formula was determined by comparing the bun heights to the control using the Response Surface Method (RSM). The program, originally described by Walker and Parkhust (1984), uses a second order regression equation and currently runs under MS DOS.

Once an acceptable combination that was near the control height was determined, the same formula was made with both hard red and hard white wheats, and their colors were compared by the Agtron model M-500-A (Magnison Engineering, San Jose, CA). A green filter was used on the Agtron, and the scale was calibrated at 0 and 100, with 0 being black and 100 white, reference disks.

Firmness was measured by the Voland-Stevens Texture Analyzer model TA-1000 (Voland Corporation, Hawthorne, N.Y.). The indenter diameter was 3.65 cm, and the cross head speed was 2mm/sec. The buns were sliced 1 in. (2.54 cm) from the bottom and compressed a distance of 6mm (25% of the slice) from the top of the slice. These measurements were based on the AACC method for the Universal Testing Machine (Baker and Ponte 1987).

Total dietary fiber and proximate analyses were obtained for the baked buns.

**Sensory Evaluation**

The objectives of the sensory tests were to determine if a difference could be detected between hard red winter and hard white winter wheats when used in a hamburger bun, and how much each of these buns was "liked".

The four formula types were examined on different days. Both the triangle difference and the hedonic design sensory tests included a balanced presentation of samples. The triangle test asked "Which is the different sample?" The hedonic test was a nine-point scale anchored with words "dislike extremely" and "like extremely."

The panelists (approximately 82 for each formula) were nonprofessionals of differing ages, gender, education, and economic backgrounds. They were selected only on their availability; no screening was performed. No panelists trained in sensory analysis were allowed to participate. The same panelists completed both the difference test and the hedonic rating scale. Testing was conducted in a sensory laboratory, in partitioned booths, and under controlled environmental conditions. For the difference test, red lights were used to mask any visual color differences. Then the red lights were turned off, fluorescent lights were turned on, and the booths were

cleaned out before the hedonic sample trays and ballots were placed in front of the panelists.

The sample buns had been baked the day before each test, cooled, and placed in odor-free plastic bags. One hour before the testing began, the buns were cut into eighths and replaced in the bags. Samples were placed on white styrofoam trays but were not allowed to stand longer than 3 minutes before testing. All samples were coded with three-digit identification codes.

Before entering the testing lab, panelists were instructed on how to perform each test, using a sample ballot.

1) Samples were to be examined left to right, 2) a sip of water was to be taken before each sample, 3) panelists were to eat as much of the sample as they desired, and 4) for the triangle test, one sample was to be chosen as different from the other two. The hedonic ballot was explained as "we want to know how much you like or dislike the sample." Purified water was used for rinsing; panelists were allowed to work at their own pace.

## RESULTS & DISCUSSION

### Wheats

The percentages of each stream in the milling process are reported in Table III. Sieve analysis for the bran ground in the Fitz Mill are reported in Table IV.

### Cracked Wheat Addition

Table V reports the actual height obtained from three replicates and RSM program predicted height. Figure 4 shows the results of cracked wheat and vital gluten addition. The chart was obtained by entering data from three replicate bakes into the RSM program and arriving at predicted points. These points were then graphed to show the second order regression lines. The control line was obtained from the mean of the controls. Based on the graph, additions of 30 percent cracked wheat with 18 percent vital gluten were the highest that would still maintain the desired control height and also produce a reasonably acceptable bun appearance.

### Flaked Wheat Addition

Table VI reports the actual height and predicted heights for flaked wheat buns. Results shown in Fig. 5 were obtained in the same manner as those in Fig. 4. Forty percent flaked wheat with 10% vital gluten was chosen as the highest addition that could be made while maintaining control height and acceptable appearance.

TABLE III

PERCENT FROM EACH MILLING FRACTION

| | Red | White |
|---|---|---|
| Flour | 75.2 | 76.9 |
| Bran | 15.0 | 14.5 |
| Shorts | 5.6 | 5.2 |
| Germy Shorts | 3.9 | 3.2 |
| Germ | 0.3 | 0.2 |
| | 100.0 | 100.0 |

TABLE IV

SIEVE ANALYSIS FOR GROUND BRAN*

| Time (min.) | U.S. Standard Sieve | Wheat White | Wheat Red |
|---|---|---|---|
| 2 | over # 20 | trace | trace |
| 2 | 40 | 37.0% | 37.9% |
| 3 | 60 | 27.0 | 27.4 |
| 3 | 80 | 27.6 | 29.5 |
| 3 | 100 | 0.5 | 0.5 |
| 3 | thru # 100 | 5.2 | 4.7 |

*started with 200 g

data reported as average of two replicates

TABLE V

CRACKED WHEAT BUNS HEIGHT

| Cracked Wheat | Vital Gluten | Absorption | Actual Height (cm)[1] | Predicted Height (cm)[2] |
|---|---|---|---|---|
| 0% | 0% | 58% | 4.86, 4.85, 4.72 | 4.83 |
| 10 | 5 | 65 | 4.75, 4.85, 4.73 | 4.69 |
| 20 | 5 | 67 | 4.27, 4.57, 4.45 | 4.44 |
| 30 | 5 | 69 | 4.28, 4.39, 4.16 | 4.28 |
| 10 | 10 | 70 | 4.75, 4.93, 4.76 | 4.86 |
| 20 | 10 | 72 | 4.63, 4.59, 4.49 | 4.59 |
| 30 | 10 | 74 | 4.43, 4.38, 4.39 | 4.39 |
| 10 | 15 | 75 | 5.17, 5.09, 4.96 | 5.05 |
| 20 | 15 | 77 | 4.79, 4.79, 4.68 | 4.75 |
| 30 | 15 | 79 | 4.47, 4.54, 4.53 | 4.52 |
| 30 | 20 | 84 | 4.60, 4.69, 4.68 | 4.67 |
| 40 | 20 | 86 | 4.50, 4.63, 4.42 | 4.50 |

[1]Each value was the average of six hamburger buns

[2]Value obtained from RSM Program with imput from the three replicate bakes (actual heights).

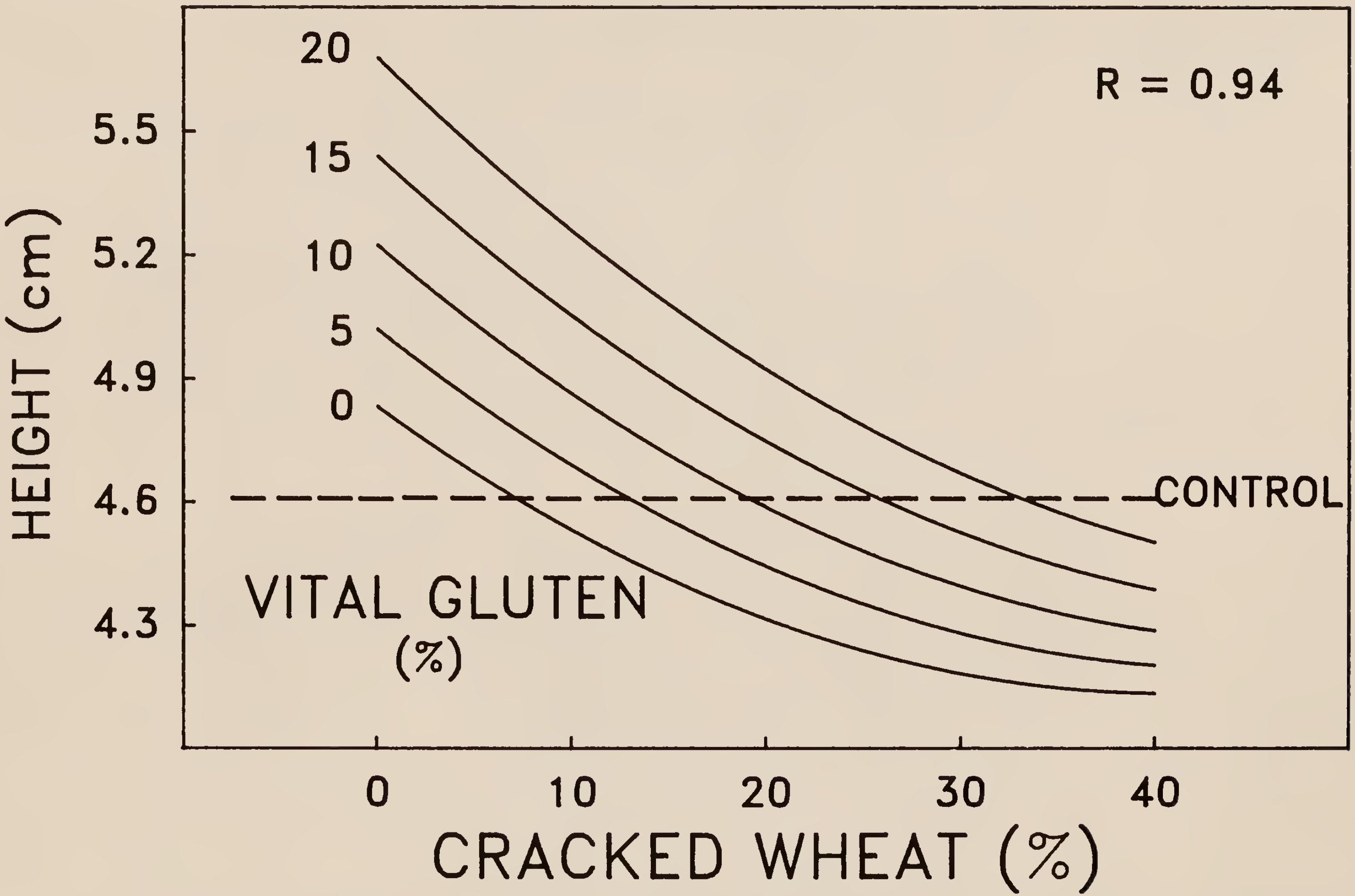


Fig. 4 Hamburger Bun Height with varying amounts of Vital Gluten and Cracked Wheat

TABLE VI

FLAKED WHEATS BUN HEIGHT

| Flaked Wheat | Vital Gluten | Absorption | Actual Height (cm)[1] | Predicted Height (cm)[2] |
|---|---|---|---|---|
| 0% | 0% | 58% | 4.70, 4.77, 4.66 | 4.71 |
| 10 | 5 | 67 | 4.88, 4.77, 4.77 | 4.85 |
| 10 | 10 | 72 | 4.98, 5.18, 4.85 | 4.99 |
| 10 | 15 | 77 | 5.22, 4.91, 5.16 | 5.07 |
| 20 | 5 | 71 | 4.77, 4.83, 4.88 | 4.75 |
| 20 | 10 | 76 | 4.93, 4.92, 4.95 | 4.93 |
| 20 | 15 | 81 | 5.02, 5.01, 4.92 | 5.06 |
| 30 | 5 | 75 | 4.47, 4.63, 4.54 | 4.58 |
| 30 | 10 | 80 | 4.84, 4.75, 4.79 | 4.81 |
| 30 | 15 | 85 | 4.95, 4.94, 5.17 | 4.98 |
| 40 | 20 | 94 | 4.92, 5.06 ---- | 4.98[3] |

[1]Each value was the average of six hamburger buns

[2]Value obtained from RSM Program with imput from the three replicate bakes (actual heights).

[3]Two replicates for this value.

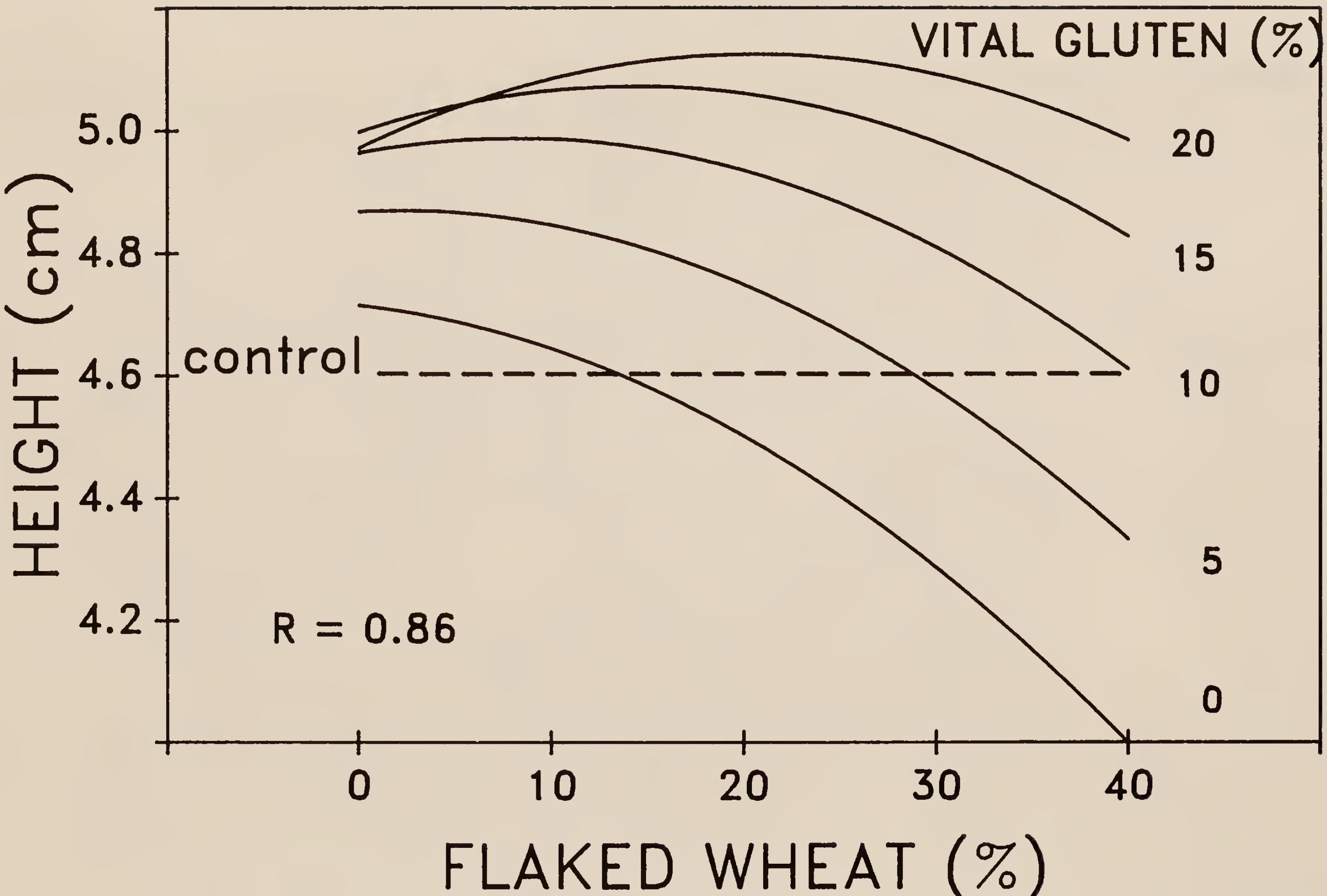

Fig. 5 Hamburger Bun Height with varying amounts of Vital Gluten and Flaked Wheat

**Bran Addition**

Table VII reports the actual height and predicted heights for bran addition. Results in Fig. 6 were also obtained in the same manner as those in Fig. 4. It was determined that 20% bran addition with 19% vital gluten was the best combination.

**Whole Wheat Replacement**

Table VIII reports three replicate bakes actual height and predicted height by the RSM program. Results in Fig. 7 were obtained in the same manner as those in Fig. 4. Whole wheat could replace white flour at 30% with 10% vital gluten addition, while still maintaining control height. Because the aim was to replace white flour at the highest level possible, the rest of the tests were done at 50% whole wheat replacement, which is similar to industry practice. Ten percent vital gluten addition was used, because the small increase in height with 15% addition probably would not merit the higher cost.

**Measurements**

Fig. 8 has a photograph of all the buns baked from different formulas.

Table IX contains the results of the firmness and color measurements. The Voland-Stevens results do not indicate a significant difference between firmness with red and white wheats (none was expected), but there was a difference between formulas, with the control bun being the firmest and

TABLE VII

BRAN BUNS HEIGHT

| Bran | Vital Gluten | Absorption | Actual Height (cm)[1] | Predicted Height (cm)[2] |
|---|---|---|---|---|
| 0% | 0% | 58% | 4.52, 4.60, 4.69 | 4.63 |
| 10 | 5 | 73 | 4.59, 4.46, 4.79 | 4.60 |
| 10 | 10 | 78 | 4.86, 4.82, 4.76 | 4.66 |
| 10 | 15 | 83 | 4.57, 4.63, 4.92 | 4.74 |
| 15 | 5 | 78 | 4.34, 4.52, 4.35 | 4.45 |
| 15 | 10 | 83 | 4.49, 4.60, 4.68 | 4.55 |
| 15 | 15 | 88 | 4.56, 4.38, 4.73 | 4.66 |
| 20 | 5 | 83 | 4.18, 4.21, 4.34 | 4.21 |
| 20 | 10 | 88 | 4.43, 4.29, 4.30 | 4.35 |
| 20 | 15 | 93 | 4.25, 4.51, 4.44 | 4.49 |
| 20 | 20 | 98 | 4.66, 4.69, 4.74 | 4.64 |
| 25 | 20 | 103 | 4.57, 4.44, 4.34 | 4.42 |

[1]Each value was the average of six hamburger buns

[2]Value obtained from RSM Program with imput from the three replicate bakes (actual heights).

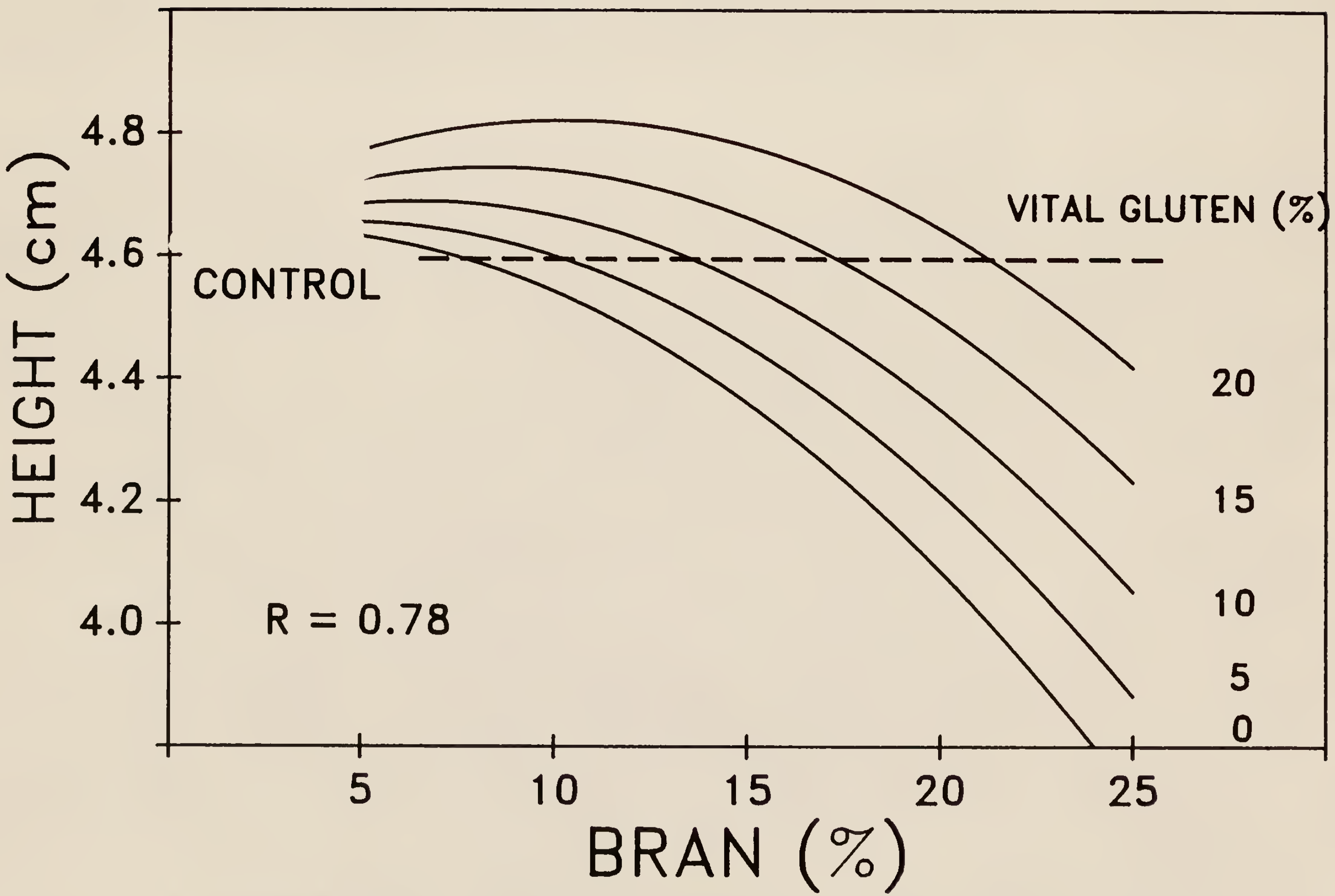


Fig. 6 Hamburger Bun Height with varying amounts of Vital Gluten and Bran

TABLE VIII

WHOLE WHEAT BUNS HEIGHT

| Whole Wheat | Vital Gluten | Absorption | Actual Height (cm)[1] | Predicted Height (cm)[2] |
|---|---|---|---|---|
| 0% | 0% | 58% | 4.56, 4.49, 4.52 | 4.55[3] |
| | | | 4.35, 4.80, 4.59 | |
| 20 | 5 | 65 | 4.29, 4.51, 4.65 | 4.51 |
| 20 | 10 | 70 | 4.47, 4.74, 4.70 | 4.65 |
| 20 | 15 | 75 | 4.54, 4.70, 4.80 | 4.69 |
| 40 | 5 | 67 | 4.22, 4.32, 4.37 | 4.28 |
| 40 | 10 | 72 | 4.41, 4.51, 4.40 | 4.43 |
| 40 | 15 | 77 | 4.41, 4.61, 4.54 | 4.47 |
| 60 | 5 | 69 | 3.96, 4.09, 4.16 | 4.10 |
| 60 | 10 | 74 | 4.15, 4.34, 4.35 | 4.25 |
| 60 | 15 | 79 | 4.19, 4.28, 4.19 | 4.30 |
| 80 | 15 | 81 | 3.89, 4.29, 4.32 | 4.18 |

[1]Each value was the average of six hamburger buns

[2]Value obtained from RSM Program with imput from the three replicate bakes (actual heights).

[3]Six replicates for this value.

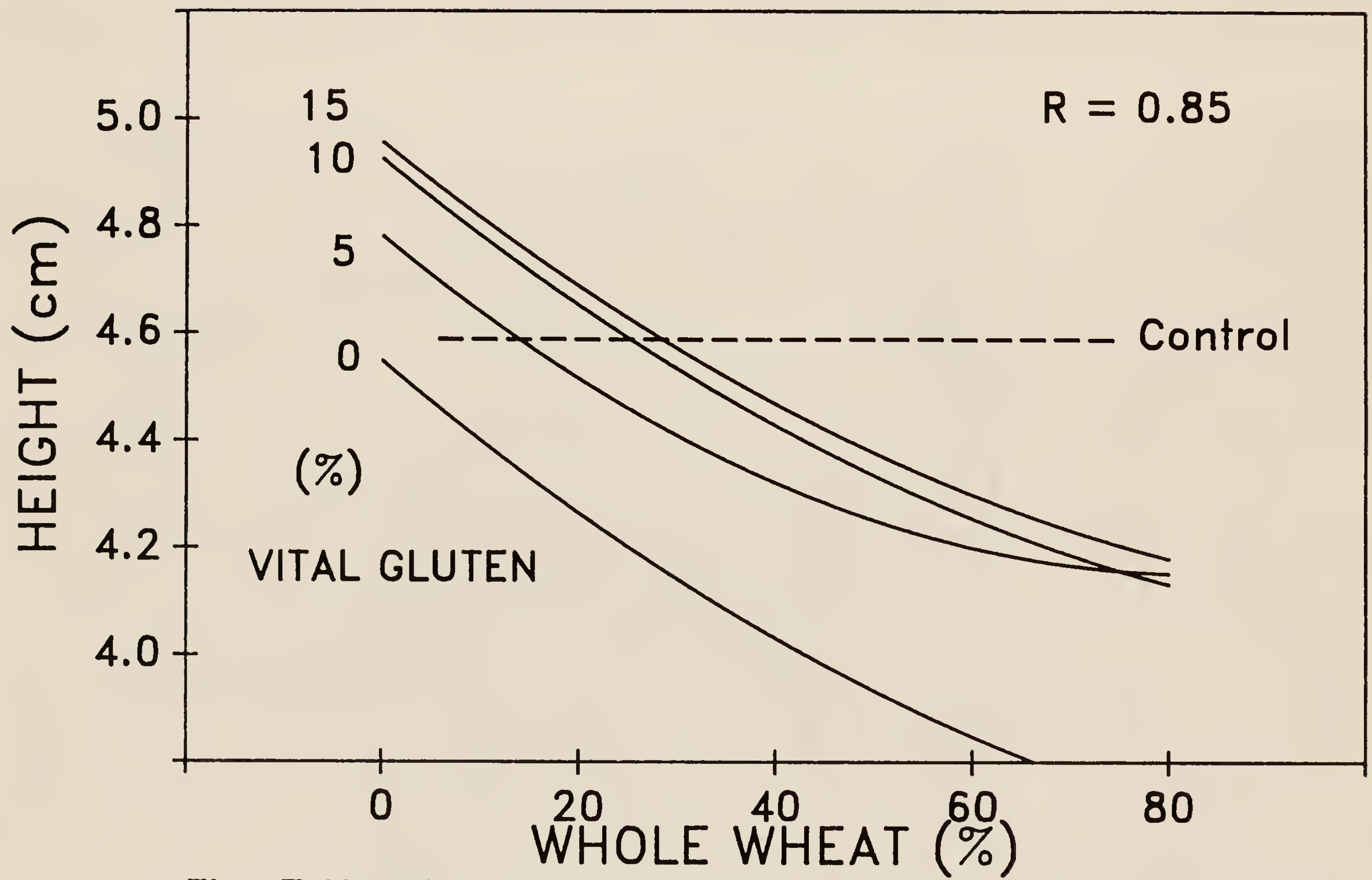


Fig. 7 Hamburger Bun Height with varying amounts of Vital Gluten and Whole Wheat

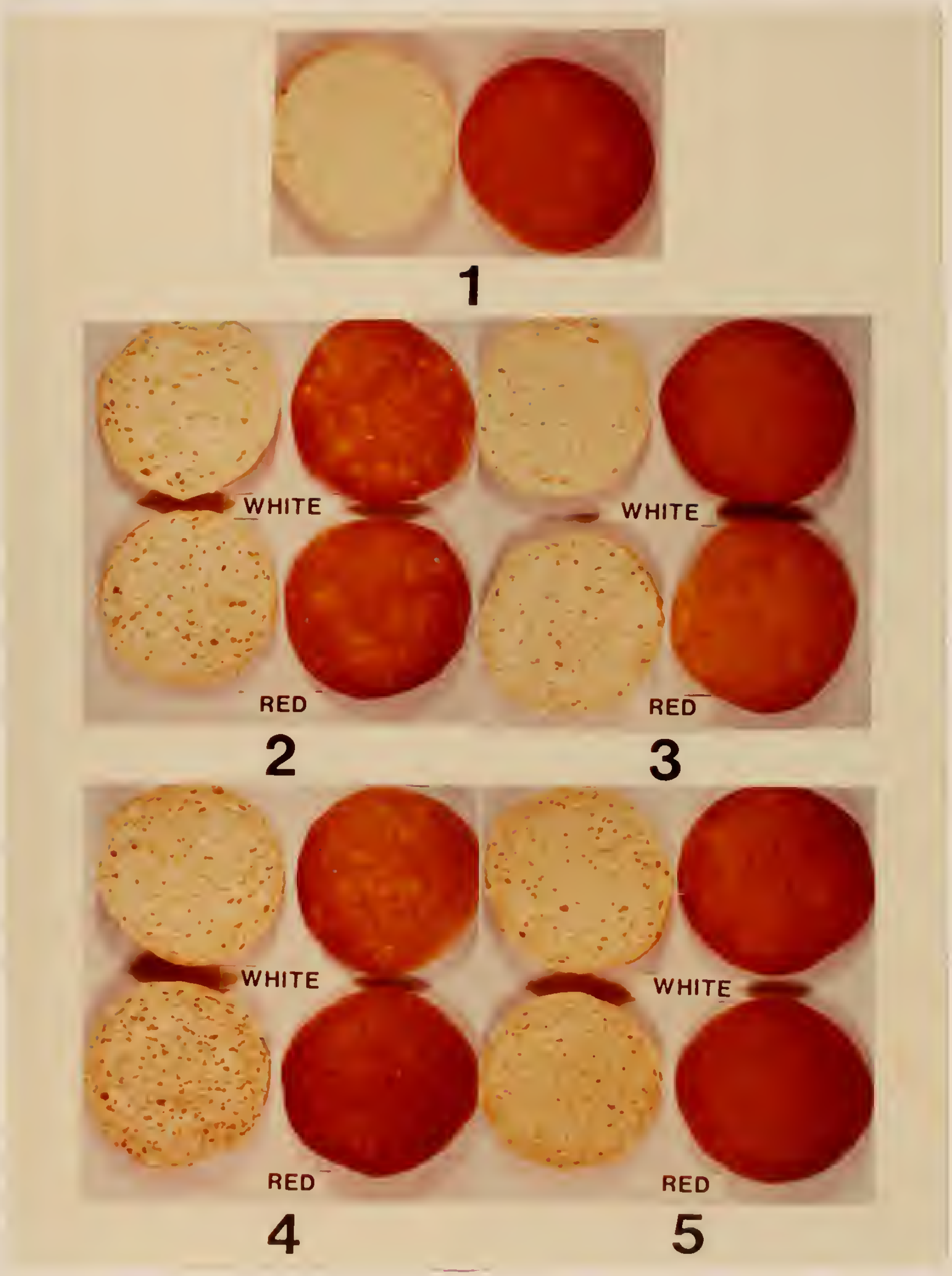


Fig. 8 Photograph of Hamburger Buns made from Hard Red and White Winter Wheats: 1) control; 2) 30% cracked wheat, 18% vital gluten; 3) 40% flaked wheat, 10% vital gluten; 4) 20% bran, 19% vital gluten; 5) 50% whole wheat, 10% vital gluten.

TABLE IX

VOLAND-STEVENS & AGTRON MEASUREMENTS

| Formula Type | % Material | % Vital Gluten | Voland-Stevens white | Voland-Stevens red | Agtron Value white | Agtron Value red |
|---|---|---|---|---|---|---|
| Cracked | 30 | 18 | 185 ± 4 | 196 ± 5 | 51 ± 1 | 51 ± 2 |
| Flaked | 40 | 10 | 246 ± 6 | 249 ± 6 | 56 ± 1 | 50 ± 1 |
| Bran | 20 | 19 | 129 ± 3 | 122 ±15 | 44 ± 1 | 39 ± 1 |
| Whole Wheat | 50 | 10 | 146 ± 5 | 158 ±14 | 50 ± 1 | 43 ± 1 |
| Control | 0 | 0 | 298 ± 10 | | 66 ± 1 | |

the bran formula the least firm. The Agtron results showed that the control bun, with highest value, was the lightest in color. The buns containing flaked wheat, bran, or whole wheat flour from white wheat where lighter in color than the red-wheat buns, as expected.

Table X contains proximate, neutral detergent fiber, and total dietary fiber analysis. As expected, the protein increased with the increase in vital gluten. Both the neutral detergent fiber and the total dietary fiber results indicated that the bran buns contained the most fiber followed by whole wheat, flaked and cracked wheat buns. Each 50 g size white wheat bran bun contains 7.5g, whole wheat 6.8g, flaked wheat 6.0g, and cracked wheat 5.5g of total dietary fiber. The National Cancer Institute recomends 25-35g of fiber consumption per day.

**Sensory Evaluation**

The triangle test results are summarized in Table XI. In all cases, the panelists found a significant taste difference between the red-wheat and the white-wheat hamburger buns. The preference tests results are included in Table XII. There was no significant difference among any of the formulas or between red versus white wheat. Despite the clear taste differences between the red-wheat and the white-wheat hamburger buns, the panelists showed no clear preference for one over the other.

Table X

Proximates, Neutral Detergent Fiber (NDF) & Total Dietary Fiber (TDF)

of Hamburger Buns (%)

| | Control | Cracked | | Flaked | | Bran | | WW | |
|---|---|---|---|---|---|---|---|---|---|
| | | White | Red | White | Red | White | Red | White | Red |
| Moisture[1] | 32.4 | 32.8 | 33.5 | 35.3 | 35.0 | 38.3 | 36.9 | 34.6 | 35.4 |
| Ash[2] | 3.5 | 3.3 | 2.6 | 3.5 | 3.6 | 3.9 | 2.9 | 2.7 | 3.1 |
| Crude Fiber[2] | 0.2 | 0.3 | 0.4 | 0.4 | 0.5 | 1.3 | 1.2 | 0.6 | 0.7 |
| Protein[2,3] | 11.9 | 18.9 | 19.2 | 15.9 | 16.1 | 20.4 | 21.0 | 17.7 | 17.8 |
| Fat[2] | 9.3 | 6.9 | 6.9 | 6.6 | 6.5 | 6.4 | 6.6 | 8.2 | 8.3 |
| NDF[2] | 2.8 | 5.4 | 4.9 | 5.2 | 6.0 | 10.7 | 10.4 | 6.3 | 5.7 |
| TDF[2] | 5.8 | 11.0 | 10.6 | 11.9 | 10.6 | 14.9 | 17.3 | 13.7 | 15.4 |

1 Moisture of fresh hamburger bun

2 Values reported on a dry matter basis

3 N x 5.7

TABLE XI

TRIANGLE DIFFERENCE TEST OF BUNS USING

HARD RED AND HARD WHITE WINTER WHEATS

| Formula Type | Number of Observations | Number Correct | Probability |
|---|---|---|---|
| Cracked Wheat | 81 | 42 | 0.003** |
| Flaked Wheat | 82 | 41 | 0.001*** |
| Bran | 84 | 39 | 0.0075** |
| Whole Wheat | 83 | 40 | 0.0027** |

***$p \leq 0.001$, very highly significantly different

**$p \leq 0.01$, highly significantly different

TABLE XII

PREFERENCE TEST RESULTS

| | Cracked | | | Flaked | | | Bran | | | Whole Wheat | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | $\bar{x}$ | s | N | $\bar{x}$ | s | N | $\bar{x}$ | s | N | $\bar{x}$ | s |
| Prefered White | 33 | | | 27 | | | 33 | | | 33 | | |
| white score | | 6.8 | 1.6 | | 7.9 | 1.0 | | 6.7 | 1.6 | | 7.7 | 0.8 |
| red score | | 4.8 | 1.6 | | 5.6 | 1.2 | | 5.1 | 1.5 | | 5.0 | 1.5 |
| Prefered Red | 34 | | | 37 | | | 26 | | | 30 | | |
| white score | | 4.6 | 1.7 | | 5.4 | 1.4 | | 5.2 | 1.3 | | 4.9 | 1.5 |
| red score | | 6.9 | 1.2 | | 7.5 | 1.0 | | 7.3 | 1.2 | | 7.5 | 1.1 |
| Equal Preference | 15 | 6.3 | 1.6 | 19 | 6.5 | 1.7 | 23 | 6.6 | 1.6 | 20 | 6.7 | 1.5 |
| Total Number of Participants | 82 | | | 83 | | | 82 | | | 83 | | |

**HARD WHITE WHEAT**

**COUSCOUS DEVELOPMENT**

ABSTRACT

Couscous is a major North African food staple. It is usually made from durum wheat semolina. Other grains such as sorghum and pearl millet are sometimes used.

Desirable characteristics of couscous are: it absorbs sauce well, each individual particle maintains its integrity when steamed, the particles do not stick to each other, and particles are uniform in size, and color. Color is an important factor in producing a desirable couscous, but there may be economic and nutritional advantages to using a whole wheat. It may be possible to produce couscous from whole hard white wheat yet maintain an acceptable color.

The objective of this work was to develop an acceptable couscous from whole hard white wheat flour. A laboratory scale method was developed, and the resulting couscous was compared with that made from hard wheat farina and with durum semolina for absorbance, particle size, color, firmness and taste.

To prepare a controlled particle size, all dry couscous was forced thru an 8W sieve and the particles were sorted into three fractions: particles passing through an 8W and remaining on a 12W sieve, through a 12W and over 18W, and that passing through the 18W. The first two fractions were used in later analysis. Material passing through the 18W was recycled.

The whole wheat couscous made from hard white winter (HWW) wheat was lighter in color as measured by the agtron than the whole wheat couscous made from hard red winter (HRW) wheat.  As the amount of bran was increased, the absorption of the couscous increased and the color became darker.

The whole wheat product was noticeably different in color and taste than couscous made from refined hard wheat flour or durum semolina, but may be an acceptable alternative to couscous made from grains such as sorghum and pearl millet.

# INTRODUCTION

Couscous is a steamed granular pasta like product made from cereal grains. It can be prepared from practically any cereal species and variety type within species. It is the principal cereal food of North Africa, the Sahara, and the Sahel. In North Africa (Egypt, Libya, Tunisia, Algeria, and Morocco), couscous is prepared from wheat, whereas in the Sahel it is prepared from pearl millet or sorghum (Sidibe et al 1982). In North Africa, couscous is made from durum wheat semolina, but other grains may be used. Durum wheat is indigenous to North Africa and consequently, it is the main cereal for many food preparations. Tradionally, the North African countries have been major durum wheat exporters to Europe (Kaup and Walker 1986).

Couscous originated with the Berbers, nomadic Arabs who probably invented it as way of preserving flour during their travels (Kibitzing 1988). Couscous versatility serves well the Saharan and Shelian pastoralist and seasonal farmers migrant life style (Sidibe et al 1982).

Couscous in North Africa is prepared by agglomerating farina or semolina. In West Africa, sorghum and pearl millet are used. Sorghum or pearl millet is decorticated and ground into flour. This flour is agglomerated and steamed (Galiba et al 1987). Tradionally in North Africa, farina or semolina is agglomerated in a large wooden or clay dish. It is sprinkled with a small amount of cold water and

salt and rolled by moving the palm of the hand in a fast motion. A little flour is added while rolling the semolina in order to make small and separate agglomerates. These agglomerates are sorted according to their size by using a sieve. Large agglomerates are crushed and rolled with a little flour, followed by another sorting. The smallest agglomerates are put together, whereas the largest are recycled into the rolling process to make smaller agglomerates. They should be about the same size; non-uniform agglomerates are undesirable (Bennani-Smire 1984). To ensure a moisture content under 13%, each household prepares an entire year's supply during the dry, summer months and places it on the flat roof of the house to dry (Kaup and Walker 1986).

Couscous in North Africa is prepared from wheat using several methods; a) whole or partially decorticated kernels are cooked and then cracked into pieces; b) farina or semolina obtained by dry milling are steamed to give the final product; or c) flour is blended with water, agglomerated, shaped, and steamed (Kaup and Walker 1986). Couscous can be prepared directly into a steamed product or it can be dried or stored indefinitely. It can be reconstituted in milk or steamed again and served with sauce (Sidibe et al 1982).

A disadvantage of couscous is the laborious, time-consuming process and skill required to make the product

(Rooney et al 1986). Couscous is prepared in three steps: milling, agglomeration and steaming. Milling is done using tradional wooden mortar and pestle for sorghum or pearl millet or by mechanical mills. Flour obtained from milling is agglomerated by blending with water to produce small particles (Galiba et al 1988). The agglomerating step is very important because too much water will yield a porridge, and too little water will give an undercooked product (Galiba et al 1987). The agglomerated particles are shaped, then cooked by steaming two or three times in a couscousiere (Galiba et al 1988). A couscousiere is a tin, aluminum or stainless steel vessel. It consists of a large, deep stock pot, topped with a perforated steamer and cover. The couscous grains are steamed in the couscoussier top part, which is first lined with a piece of thin muslin or cheesecloth (Kibitzing 1988).

The traditional and commercial processes follow the same basic steps: 1) the continuous water and semolina or farina blending; 2) agglomeration; 3) shaping; 4) steaming; 5) drying; 6) cooling; 7) grading; the couscous is separated into coarse, medium and fine grades; 8) storage. The dry couscous particle diameter is approximately 1mm. (Kaup and Walker 1986). Couscous can be stored for more than six months (Galiba et al 1987). Preparation of couscous is time-consuming but the final product is well-suited for the

Sahelian pastoralist migrant life because of its long shelf-life and versatility (Galiba et al 1988).

Factors affecting couscous quality are cereal type, milling procedure, and ability to form particles that retain their integrity when steamed (Galiba et al 1987). Desirable couscous characteristics include: 1) it absorbs sauce well; 2) each individual couscous particle maintains its integrity when steam or sauce is applied; 3) the couscous particles do not stick to one another; 4) uniform size particles. The extent to which couscous particles absorb sauce will affect the taste, as well as mouthfeel. If couscous does not absorb the sauce adequately, it will feel hard and lack the desirable smoothness. Sticky couscous is extremely undesirable, and is usually discarded (Kaup and Walker 1986).

The semolina granule size may play a role in end product quality. Semolina with a smaller particle size may contain more damaged starch, as harder wheat results both in finer particle size and higher starch damage levels. Damaged starch does absorb more water than native starch, which may be important to steam absorption by couscous. The salt effect on gluten toughening may play an important role in the couscous rheological properties, but its role in quality has not yet been proven (Kaup and Walker 1986).

Couscous is consumed for breakfast, lunch, or dinner depending upon the sauce used. It has a delicate,

particulate mouthfeel and normally a bland, cereal taste. Added sauces, milk, and condiments affect its taste, color, and acceptability (Galiba et al 1987). In main dishes couscous is generally arranged in a ring and centered by the meat and vegetable stew (Kibitzing 1988).

The objective was to develop a couscous with acceptable color from whole HWW wheat flour and compare it with couscous made from whole HRW wheat flour.

MATERIALS AND METHODS

**Milling**

In North Africa, couscous is normally made from semolina or farina; in West Africa, it is usually made from crushed decorticated sorghum or pearl millet. Couscous was made by the decortication method that is usually used for sorghum or pearl millet, but using the following wheats: HWW Wheat 88-850 (KS 84HW196 from 1988 seed increase at Hays Branch Experiment Station, Hays, KS), and a HRW Wheat 88-854 (NorKan from 1988 seed increase at Hays Branch Experiment Station, Hays, KS). These two wheats were tested for: Test Weight (AACC) Method 55-10; revised 10-27-82 (AACC 1983), 1000 Kernel Weight (the weight in grams of 1000 kernels of wheat was determined with an electronic seed counter, using a 40g sample), Pearling Value (20g of wheat was retained for 1 minute in a Strong Scott Laboratory Barley Pearler; pearling value is the percent of the original sample remaining over a 20 mesh wire after pearling).

A mini-dehuller with 10 resinoid disks (custom built, based on the design by Oomah et al 1981) was used to decorticate the wheat. Five kilograms of each wheat were decorticated for 5, 9, 13.5, or 18 minutes. Decortication percentage was calculated as the weight lost after sifting the decorticated grain thru a 2.5 mm mesh screen. One hundred kernels of each decorticated wheat was measured for

length and thickness, and the length/thickness ratio was calculated.

The decorticated wheat was ground to a flour in a Magic Mill III Model 100 (Salt Lake City, Utah). No sifters were used. Color on each of the flours was determined by the Simon Colour Grader Series IV (Henry Simon Co., Chesshire, England). Moisture, protein and ash were obtained on the flours using AACC Methods 44-15A, 46-10, and 08-01 respectively.

**Couscous Preparation**

Couscous was made from non-decorticated but ground wheats from the 9 and 18 minute decorticated flours; from HRW and HWW farina (El Bouziri and Posner 1989) - this farina met the standards of identity for farina (Code of Federal Regulations 1987); and from HWW & HRW straight grade flours - as used by Lang and Walker (1989). The couscous was prepared in a Hobart Mixer Model N-50 (Troy, OH). Three hundred grams of flour were mixed with a wire whip and a variable amount of water. The water was varied according to optimum yield when passed thru a U.S. Standard No. 14 sieve. The optimum yield was based on the most water that could be mixed in without forming dough. The objective was to pass the maximum amount of particles through a U.S. Standard No. 14 sieve without having dry flour particles.

The mixing procedure was: 1) 300 grams of flour was mixed at speed one for 1 minute without water; 2) on speed two it

was mixed 2 min. with a water addition using a spray bottle (the amount of water was controlled by weighing the full spray bottle with water and subtracting the amount desired, the bottle was weighed several times until the desired amount had been added to the flour particles); 3) the bowl was covered and mixed 2 min. on speed 3; 4) on speed 2 for two min. with more water addition; 5) the mixer was placed on speed three, covered and mixed two minutes; 6) the last water addition was at speed three for two minutes.

The particles were forced through a U.S. Standard Testing Sieve No. 14. The overs were discarded and the amount that went thru the sieve was weighed before steaming for 15 min. in a couscousiere. After steaming, the product was forced through a No. 8 U.S. Standard Testing Sieve and steamed for an additional 15 minutes. The resulting product was then spread thinly on a 13" x 9" cookie sheet, and allowed to dry at room temperature.

**Dry Couscous Tests**

Particle Size

After 24 hrs., the couscous was sieved through U.S. Standard Testing Sieves No. 8, 14, and 18. All particles were forced thru the No. 8. If they were to large, they were broken up with a rolling pin until all the couscous went through sieve No. 8. They were then sieved through a No. 14 and two fractions were obtained. Thru No. 8, over No. 14 and thru No. 14. This later fraction was sieved thru a No.

18. Two more fraction were obtained: thru No. 14 over No. 18 fraction and thru No. 18. This smallest fraction was recycled in later batches. The result was three final fractions: thru No. 8, over No. 14; thru No. 14, over No. 18; and thru No. 18.

Color Test

Dry couscous color was measured by the Agtron model M-500-A (Magnison Engineering, San Jose, CA). A green filter was used on the Agtron, and the scale was calibrated at 0 and 100, with the 0 black and 100 white reference disks.

Absorption Test

To measure couscous absorption, the samples were prepared similarly to the method described by Kaup and Walker (1986), modified to a smaller scale. One hundred sixty-seven grams of dry couscous was spread in a shallow pan. It was sprinkled with 100 g cold water that had 3.1 g of dissolved salt in it. The particles were rubbed between the palm of the hand until all particles were coated, and the pan covered with plastic film for 15 min. The particles were added to the top of the couscousiere, and steamed uncovered for 20 minutes. The grains were then spread in a shallow pan that had 13.6 g of butter cut into small pieces. The particles were rubbed between the palms of the hands until they were coated, and steamed for an additional 15 minutes. The samples were weighed to determine how much moisture they had absorbed. Cooked sample moisture was also obtained with the

Brabender Moisture Tester No. 918 Type DH5 (Rochelle, N.Y.). The samples were in the 130 F oven for 3 hours.

Other Tests

Neutral Detergent Fiber (Goering and Van Soest 1970) and proximate analyses (AOAC Methods 7.007 for moisture, 7.009 for ash, 7.015 for protein, 7.061 for fat, and 7.071 for crude fiber) were obtained for the dry samples.

Dry Couscous sample photographs were also taken.

**Cooked Couscous Tests**

Color Test

Cooked couscous colors were obtained from the Agtron with the same calibration as for dry couscous. The cooked samples were prepared in the same method as for the absorption test. Photographs were taken of the cooked samples.

Sensory Evaluation

Couscous for sensory evaluation was prepared in the following manner. One hundred eighty-five grams of dry couscous was hydrated for 3 min. with 150 g of water that had 0.3 g of salt dissolved in it. In a large frying pan, 2 oz. of butter were melted, the couscous added, and cooked over medium heat for 4 min. while stirring continuously.

The sensory test objective was to determine which samples were acceptable to North Africans who normally eat durum wheat semolina couscous. Seven North Africans (at least one each from Algeria, Tunisia and Morocco; one female and six

males) who were accustomed to eating durum semolina couscous were asked to participate in sensory evaluation.

Testing was conducted in the baking laboratory. Fluorescent lights were used. The samples were prepared the day before the test and placed in odor-free plastic bags in the refrigerator. While the panelist were evaluating the dry samples, the four cooked samples weighing approximately 10g each were heated 45 sec. in a microwave (Sharp Carousel Browning Oven, Sharp Electronics Corp., Model No. R-8200, 650 watts, 2450 megahertz). This ensured the samples would be warmed the same amount. All samples were coded with three-digit identification numbers.

Six dry samples (HWW & HRW at 0, 9 min. and 18 min. decortication) were placed before the panelists in random order. The panelists were then asked which of the samples were visually acceptable to them. The purpose was to simulate a situation in which they might be buying the dry product.

These samples were then removed and replaced by four of the six cooked samples. These were also placed in random order. The panelist were asked to take a sip of water before each samples and to taste them from left to right in the order given. The ballot asked them to circle the samples that were acceptable to them.

RESULTS & DISCUSSION

**Milling**

Decortication results are reported in Table XIII & Fig. 9. After equal decortication times, the red wheat lost a greater percentage than did the white. This may have been because the red kernels were smaller, with more kernels per each 5 Kg. sample. Table XIV reports kernel characteristics which indicate that the white wheat kernels were bigger and harder. One hundred kernels of each decorticated sample were measured for length and thickness (Table XV). The ratio length to thickness is graphed in Fig. 10. The ratio (length/thickness) loss rate was faster for the white wheat than the red wheat which was at more even rate, but the percent decortication indicated a greater loss for the red wheat.

The flour obtained from the decorticated wheats became lighter in color as degree of decortication increased, indicated by the smaller numbers (Table XVI). The ground white non-decorticated wheat had a color value equal to that of red wheat after 18 min. decortication. This means that when the red wheat was decorticated by 33.0%, its flour color was equal to that of white wheat without decortication.

Ground flour analysis are reported in Table XVII & Fig. 11 & 12.

TABLE XIII

WHEAT DECORTICATION

| | Red | | White | |
|---|---|---|---|---|
| Time (minutes) | weight after sifting (g) | percent decortication | weight after sifting (g) | percent decortication |
| 0 | 5000.0 | 0 | 5000.0 | 0 |
| 5 | 4539.5 | 9.2 | 4570.4 | 8.6 |
| 9 | 4086.8 | 18.3 | 4306.2 | 13.9 |
| 13.5 | 3711.0 | 25.8 | 3857.0 | 22.9 |
| 18 | 3349.6 | 33.0 | 3536.3 | 29.3 |

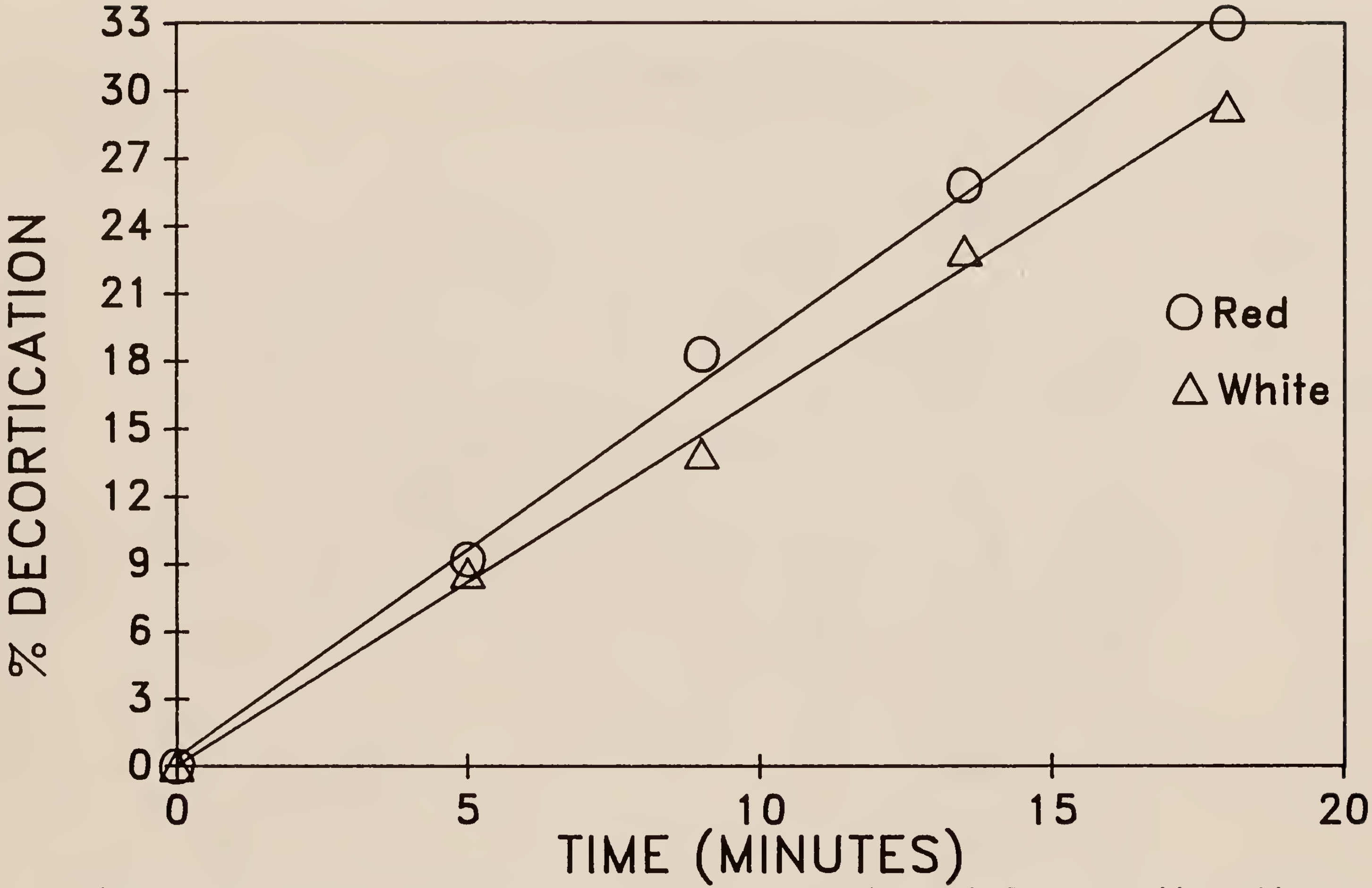


Fig. 9 Red and White Hard Wheat Decortication at various time intervals

TABLE XIV

WHEAT CHARACTERISTICS

| Test | White | Red |
|---|---|---|
| Test Wt. (lbs. per bushel) | 63.6 | 62.0 |
| 1000 Kernel Weight (g) | 30.4 | 22.9 |
| Pearling Value (%) | 73.5 | 71.0 |

TABLE XV

AVERAGE DIMENSIONS OF 100 WHEAT KERNELS

| Decortication Time (minutes) | White Length (mm) | White Thickness (mm) | White Ratio L/T | Red Length (mm) | Red Thickness (mm) | Red Ratio L/T |
|---|---|---|---|---|---|---|
| 0 | 6.05 ± 0.36 | 2.40 ± 0.19 | 2.52 | 5.48 ± 0.47 | 2.40 ± 0.28 | 2.28 |
| 5 | 5.21 ± 0.38 | 2.38 ± 0.18 | 2.19 | 4.79 ± 0.52 | 2.15 ± 0.25 | 2.23 |
| 9 | 5.02 ± 0.42 | 2.38 ± 0.20 | 2.11 | 4.47 ± 0.46 | 2.23 ± 0.28 | 2.00 |
| 13.5 | 4.79 ± 0.53 | 2.38 ± 0.16 | 2.01 | 4.25 ± 0.59 | 2.15 ± 0.29 | 1.98 |
| 18 | 4.43 ± 0.58 | 2.30 ± 0.18 | 1.93 | 3.93 ± 0.62 | 2.15 ± 0.27 | 1.83 |

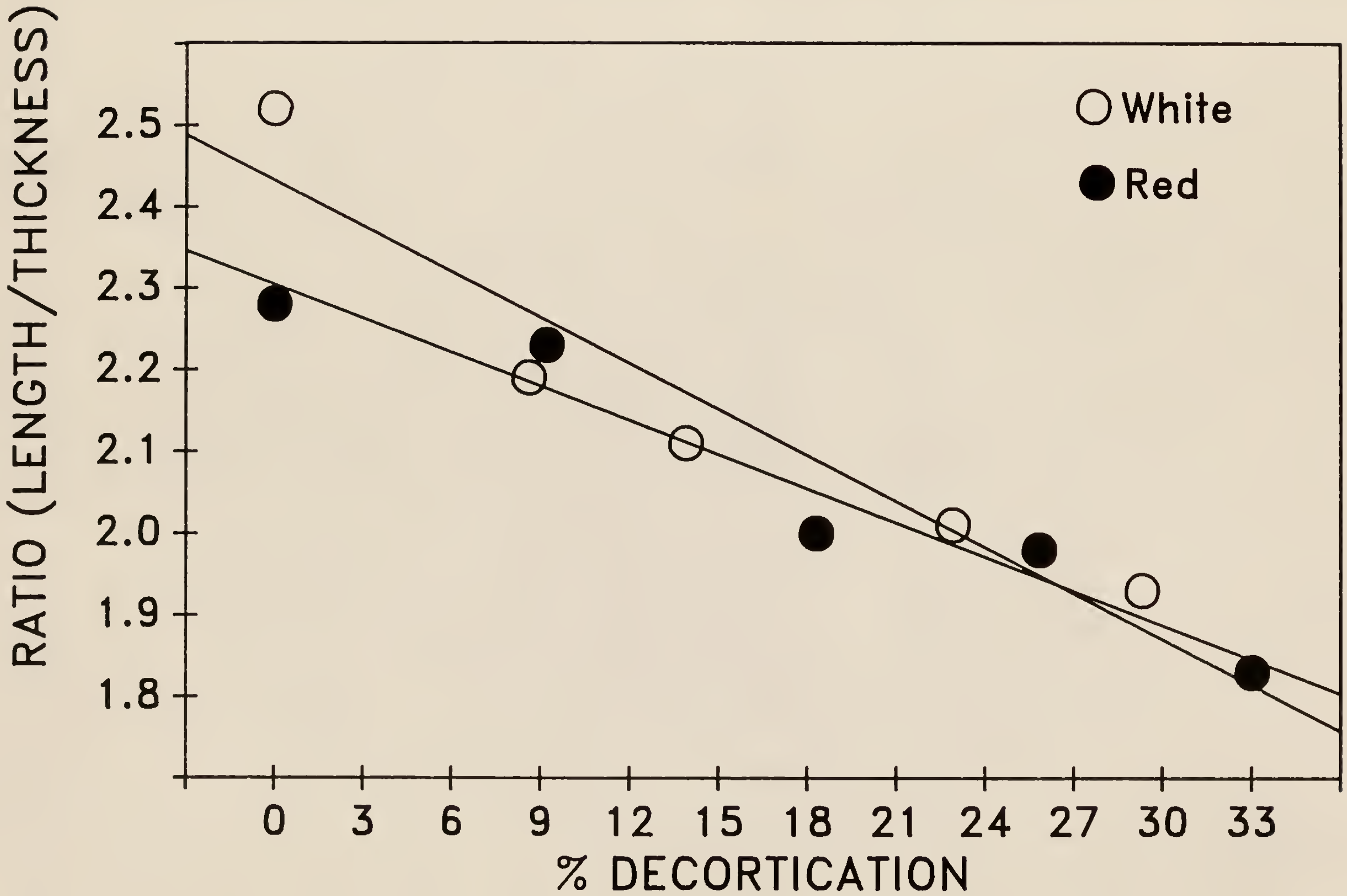


Fig. 10 The Ratio (Length/Thickness) of 100 Red and White Wheat Decorticated Kernels

TABLE XVI

FLOUR COLOR (SIMON*)

| Samples | White Wheat | Red Wheat |
|---|---|---|
| Farina | -4.0 | -1.8 |
| Decortication Time (min.) | | |
| 0.0 | 13.7 | 18.1 |
| 5.0 | 9.8 | 14.8 |
| 9.0 | 8.6 | 14.6 |
| 13.5 | 8.2 | 14.2 |
| 18.0 | 7.7 | 13.7 |

*lower number indicates lighter color

TABLE XVII

FLOUR ANALYSIS AT VARYING DECORTICATION LEVELS

| | Moisture | | Protein[1,2] | | Ash[1] | |
|---|---|---|---|---|---|---|
| | White | Red | White | Red | White | Red |
| Farina | 11.4% | 11.7% | 12.5% | 13.0% | 0.44% | 0.45% |
| Decortication (minutes) | | | | | | |
| 0 | 8.8 | 8.4 | 15.7 | 17.1 | 1.57 | 1.71 |
| 5 | 9.9 | 8.8 | 15.2 | 16.5 | 1.52 | 1.47 |
| 9 | 10.0 | 8.8 | 15.1 | 16.5 | 1.23 | 1.39 |
| 13.5 | 10.1 | 8.3 | 14.5 | 16.2 | 1.06 | 1.37 |
| 18 | 9.9 | 8.4 | 13.6 | 15.6 | 1.04 | 1.26 |

1 reported on dry matter basis

2 N x 5.7

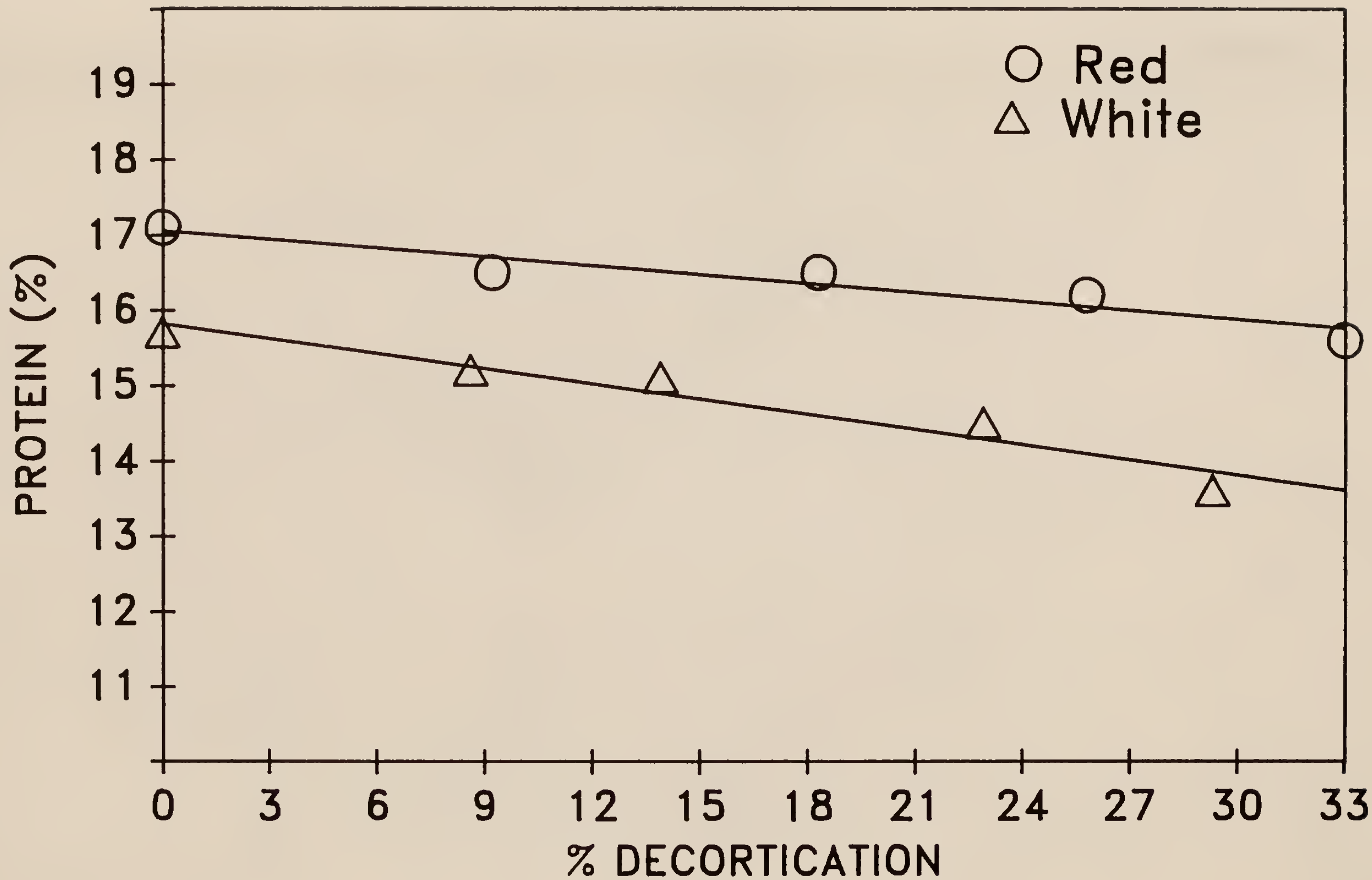


Fig. 11 Red and White Hard Wheat Protein at varying Decortication Percentages

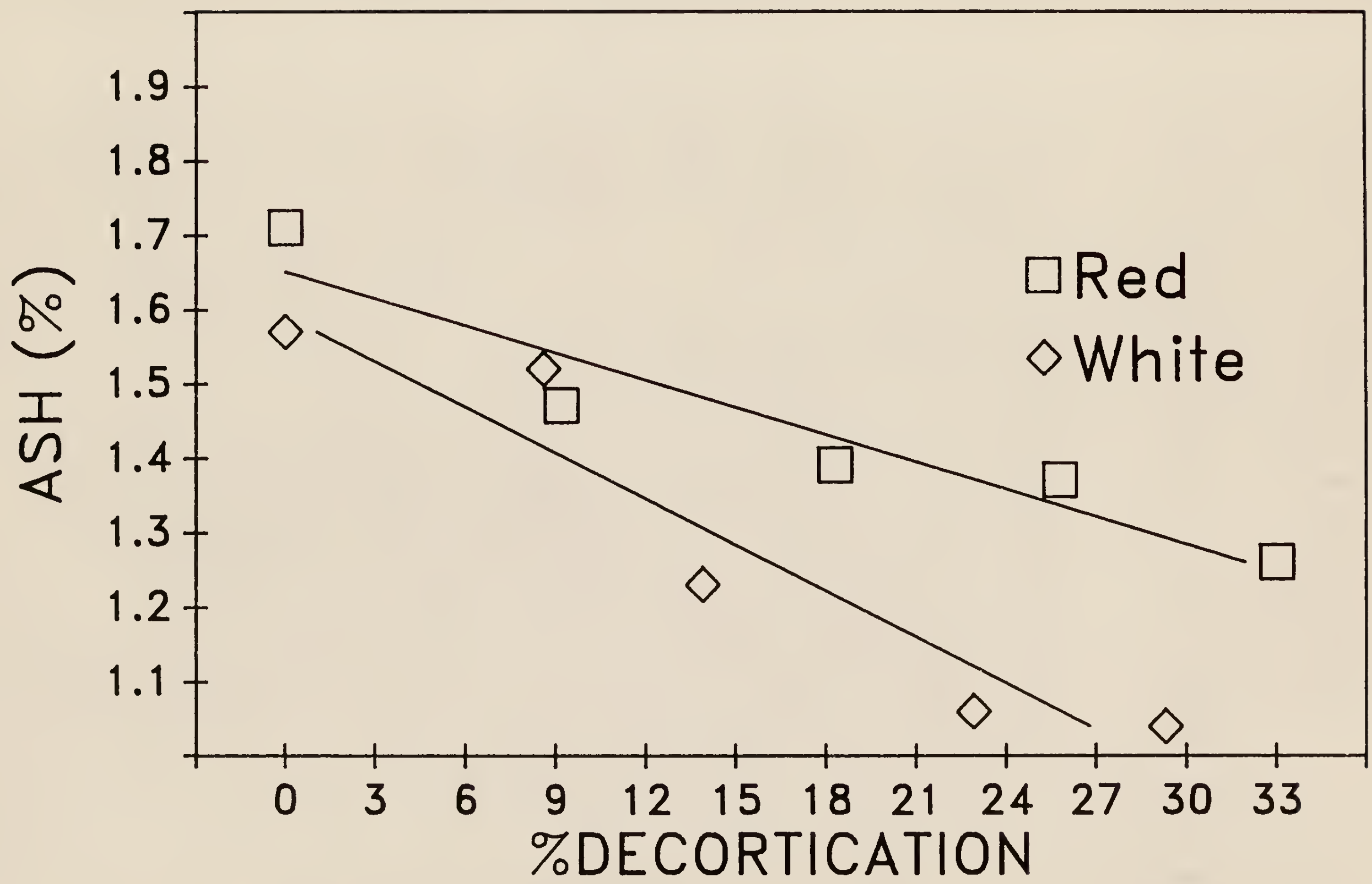


Fig. 12 Red and White Hard Wheat Ash at varying Decortication Percentages

**Couscous Preparation**

The water absorption used, and room humidity during couscous preparation is shown on Table XVIII. The humidity appeared to affect the absorption. If the room humidity was high, it took less water to produce the same couscous yield. The yield went down when there was to much water, and the couscous became almost like a dough and would not pass through the sieve as distinct particles. If this work were to be repeated at other humidity levels, the absorptions would need to be different. The absorptions were arrived at as the highest amount of couscous that could be made, passing thru a U.S. Standard No. 14 sieve and not feel dry. A simple correlation between humidity and absorption was not found. This would require further study.

There was a definite increase in absorption as the decortication level went down (Table XVIII). This researcher would have expected farina and flour to have different absorptions based on the difference in particle size. This was not the case, but the room humidity was much higher the days the flour samples were made and this could account for the same absorption. If these two samples were made at the same room humidity levels, it is likely that the flour samples would have a higher absorption.

Couscous weight after passing thru the No. 14 sieve, and the numbers of batches are reported in Table XIX. The farina samples gave the largest couscous yield before

TABLE XVIII

ROOM HUMIDITY AND FLOUR ABSORPTION TO MAKE COUSCOUS

| | Red Wheat | | White Wheat | |
|---|---|---|---|---|
| Samples | Humidity | Absorption | Humidity | Absorption |
| Farina | 46% | 31.3% | 52% | 31.3% |
| Flour | 71 | 31.3 | 88 | 31.3 |
| 18 Min. D* | 48 | 42.7 | 49 | 41.0 |
| 9 Min. D* | 38 | 44.3 | 50 | 42.7 |
| No D* | 31 | 47.7 | 58 | 47.7 |

*Decortication

TABLE XIX

WEIGHT AFTER MAKING RAW COUSCOUS & BEFORE STEAMING

| | Red Wheat | | White Wheat | |
|---|---|---|---|---|
| Samples | Batches | Avg. (g) | Batches | Avg. (g) |
| Farina | 9 | 345.3 ± 12.2 | 10 | 343.3 ± 14.3 |
| Flour | 18 | 282.9 ± 20.8 | 16 | 291.0 ± 21.8 |
| Decortication (minutes) | | | | |
| 0 | 11 | 312.6 ± 34.5 | 15 | 302.2 ± 18.6 |
| 9 | 15 | 286.5 ± 22.1 | 13 | 258.5 ± 17.8 |
| 18 | 13 | 305.6 ± 14.9 | 11 | 306.4 ± 22.4 |

steaming, and fewer batches were made. The 9 min. decortications were the lowest yielding in raw couscous. This may be due to a high absorption level from the room humidity which caused the raw couscous levels to be low.

**Dry Couscous Tests**

Particle Size

Results are reported in Table XX both by total yield in weight and by percentage. Except in the case of flour, the white wheat yielded the largest particle size in the highest percentage, which is the most desirable fraction. Commercial durum semolina couscous had the largest particle size fraction (thru No. 8, over No. 14).

Color Test

The couscous Agtron color test (Table XXI), although done on a different instrument, shows results similar to the flours they were made from. Couscous made from non-decorticated white wheat was very close in color to the 18 min. decorticated red wheat. A higher number, in this case, means lighter color. This could be an advantage when milling to a color specification; the red wheat has to be decorticated 18 min. and 33.0% wheat is removed to obtain the same color as a whole white wheat. These samples are not truly the same color. The red wheat samples appear brown and the white wheat samples have a yellowish color.

The commercial durum semolina couscous samples are close in color to the couscous made from flour when measured by

TABLE XX

COUSCOUS PARTICLE SIZE

| Samples | WEIGHT (g) | | | | | |
|---|---|---|---|---|---|---|
| | Red Wheat | | | White Wheat | | |
| | 8W[1] | 14W[2] | 18W[3] | 8W[1] | 14W[2] | 18W[3] |
| Farina | 857.9 | 570.1 | 528.0 | 812.6 | 537.8 | 423.4 |
| Flour | 825.0 | 1049.1 | 589.0 | 596.8 | 1055.1 | 609.5 |
| 18 Min. D[4] | 716.2 | 842.4 | 298.5 | 859.0 | 672.0 | 211.8 |
| 9 Min. D[4] | 774.3 | 959.6 | 242.1 | 1084.4 | 772.2 | 172.2 |
| No D[4] | 429.4 | 654.2 | 447.8 | 760.7 | 1052.9 | 149.2 |

| Samples | PERCENTS | | | | | |
|---|---|---|---|---|---|---|
| | Red Wheat | | | White Wheat | | |
| | 8W[1] | 14W[2] | 18W[3] | 8W[1] | 14W[2] | 18W[3] |
| Farina | 43.8 | 29.2 | 26.9 | 45.8 | 30.3 | 23.8 |
| Flour | 33.5 | 42.6 | 23.9 | 26.4 | 46.7 | 26.9 |
| 18 Min. D[4] | 38.6 | 45.4 | 16.1 | 49.3 | 38.6 | 12.2 |
| 9 Min. D[4] | 39.2 | 48.6 | 12.2 | 53.5 | 38.1 | 8.5 |
| No D[4] | 28.0 | 43.2 | 29.2 | 38.8 | 53.6 | 7.6 |

[1]Thru No. 8, Over No. 14 wire screen

[2]Thru No. 14, Over No. 18 wire screen

[3]Thru No. 18 wire screen

[4]Decortication

TABLE XXI

COUSCOUS DRY COLOR (AGTRON)[1]

| Sample | Red Wheat | | White Wheat | |
|---|---|---|---|---|
| | 8W[2] | 14W[3] | 8W[2] | 14W[3] |
| Farina | 60.7 | 63.0 | 62.5 | 65.5 |
| Flour | 52.3 | 56.7 | 64.0 | 61.0 |
| 18 Min. D[4] | 23.3 | 24.7 | 32.0 | 34.7 |
| 9 Min. D[4] | 20.0 | 20.5 | 29.3 | 30.3 |
| No D[4] | 18.7 | 19.3 | 23.7 | 24.7 |

| Commercial Couscous | |
|---|---|
| Sipa | 53.7 |
| Fantastic Foods | 52.3 |

[1]0 = black, 100 = white

[2]Thru No. 8, over No. 14

[3]Thru No. 14, over No. 18

[4]Decortication

the Agtron, but when they are observed with the eye the commercial samples are yellow, the flour couscous are off white, and the farina samples are very white. With only the one exception, white wheat flour couscous, all the smaller particle samples (thru No. 14, over No. 18) were lighter in color than the larger (thru No. 8, over No. 14) size. This could be because the smaller particles are closer together and appear lighter to the instrument; there are also fewer voids for the light to get lost in.

Absorption Test

Moisture content after steaming are reported in Table XXII. There does not seem to be a trend as far as increased or decrease in moisture due to bran increasing in the couscous or difference in the particle size. When the particles were being prepared it was observed that the flour samples were lumpy. The samples with bran remained in distinct particles after this test which is a desireable characteristic in couscous.

Other Tests

Neutral detergent fiber and proximate analysis are reported in table XXIII. As the decortication increased, ash decreased which agrees with the results of the flours that the couscous was made from. The protein also agreed with the flour results. The red wheat had a higher protein level than the white wheat and the protein decreased as decortication increased. Crude fiber decreased as

TABLE XXII

COOKED COUSCOUS MOISTURES

| Samples | thru No. 8, over No. 14 moisture (%) | thru No. 14, over No. 18 moisture (%) |
|---|---|---|
| White | | |
| Farina | 52.7 | 51.0 |
| Flour | 54.7 | 53.8 |
| 18* | 53.8 | 51.3 |
| 9* | 52.9 | 52.3 |
| 0* | 53.9 | 51.7 |
| Red | | |
| Farina | 50.7 | 50.9 |
| Flour | 51.6 | 50.4 |
| 18* | 51.2 | 51.9 |
| 9* | 52.5 | 52.9 |
| 0* | 53.3 | 52.7 |

| Commercial Couscous | |
|---|---|
| Sipa | 53.7 |
| Fantastic Foods | 54.4 |

*decortication time (minutes)

TABLE XXIII

PROXIMATE & NEUTRAL DETERGENT FIBER (NDF)
OF DRY COUSCOUS (%)

| | Moisture | Ash[1] | Crude Fiber[1] | Protein[1,5] | Fat[1] | NDF[1] |
|---|---|---|---|---|---|---|
| Farina | | | | | | |
| White | | | | | | |
| 8W[2] | 14.6 | 0.53 | 0.27 | 12.5 | 0.69 | 0.85 |
| 14W[3] | 16.8 | 0.55 | 0.08 | 13.0 | 0.36 | 0.79 |
| Red | | | | | | |
| 8W[2] | 16.5 | 0.44 | 0.19 | 13.0 | 0.40 | 0.87 |
| 14W[3] | 16.2 | 0.56 | 0.08 | 12.5 | 0.64 | 0.71 |
| Flour | | | | | | |
| White | | | | | | |
| 8W[2] | 10.0 | 0.69 | 0.23 | 14.2 | 0.14 | 0.96 |
| 14W[3] | 8.8 | 0.62 | 0.22 | 14.2 | 0.72 | 0.58 |
| Red | | | | | | |
| 8W[2] | 15.6 | 0.65 | 0.13 | 13.3 | 0.30 | 0.73 |
| 14W[3] | 15.1 | 0.74 | 0.13 | 13.0 | 0.73 | 0.79 |
| 18[4] | | | | | | |
| White | | | | | | |
| 8W[2] | 12.7 | 1.10 | 1.20 | 14.1 | 2.16 | 0.82 |
| 14W[3] | 14.7 | 1.25 | 1.01 | 14.7 | 0.99 | 0.90 |
| Red | | | | | | |
| 8W[2] | 14.8 | 1.17 | 1.12 | 15.7 | 1.01 | 0.95 |
| 14W[3] | 14.4 | 1.35 | 1.13 | 15.3 | 1.91 | 0.84 |
| 9[4] | | | | | | |
| White | | | | | | |
| 8W[2] | 14.5 | 1.30 | 1.57 | 15.0 | 2.34 | 0.92 |
| 14W[3] | 15.4 | 1.35 | 1.15 | 14.7 | 1.20 | 0.96 |
| Red | | | | | | |
| 8W[2] | 13.9 | 1.40 | 1.33 | 17.0 | 1.12 | 0.72 |
| 14W[3] | 14.2 | 1.54 | 1.31 | 16.3 | 1.56 | 0.87 |
| 0[4] | | | | | | |
| White | | | | | | |
| 8W[2] | 12.8 | 1.66 | 2.04 | 15.9 | 2.75 | 0.67 |
| 14W[3] | 14.1 | 1.83 | 1.87 | 15.5 | 1.75 | 0.76 |
| Red | | | | | | |
| 8W[2] | 13.4 | 1.78 | 2.10 | 18.4 | 1.49 | 1.02 |
| 14W[3] | 13.2 | 2.00 | 2.20 | 18.4 | 1.55 | 0.80 |

[1]reported on a dry matter basis
[2]thru U.S. Standard No. 8, and over U.S. Standard No. 14
[3]thru U.S. Standard No. 14, and over U.S. Standard No. 18
[4]minutes decorticated
[5]N x 5.7

decortication increased. Both couscous made from farina and flour were low in ash, crude fiber, and protein.

Dry couscous photos are shown in Fig. 13.

**Cooked Couscous Tests**

Color Test

The cooked color test results are reported in Table XXIV. Again, the non-decorticated white wheat gave a value very close to the 18 min. decorticated red wheat. In all cases, the white wheat had an equal or higher value (higher being lighter in color) than the red wheat. The smaller particle size gave a slightly lighter colored couscous than the larger particle size. The commercial couscous was darker than the flour or farina samples. Generally, the cooked samples gave a lighter color than the dry samples.

Cooked couscous photos are shown in Fig. 14.

Sensory Evaluation

Results in Table XXV. All seven panelists, although accustomed to durum semolina couscous, found the 29.3% decorticated white wheat couscous acceptable in the dry samples. The two other white decorticated samples were found acceptable by some panelists. No panelist found the red wheat samples appearance to be acceptable in the dry form. This would indicate that if these panelists were to buy this product based on its appearance, they would prefer the white wheat samples to the red wheat.

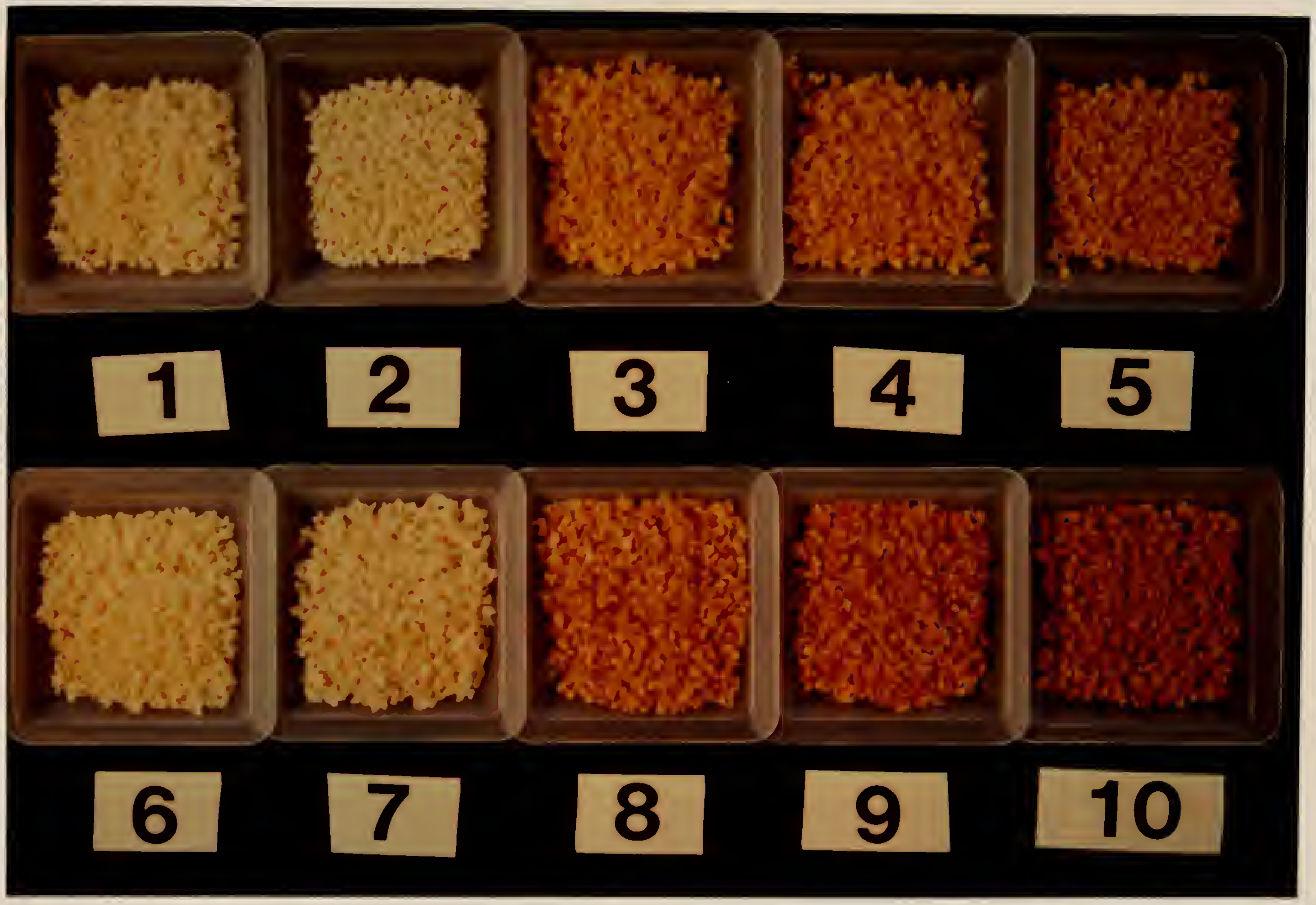


Fig. 13 Dry Couscous Photograph: 1-5 made from Hard White Winter Wheat; 6-10 made from Hard Red Winter Wheat; 1 & 6) farina; 2 & 7) conventional mill flour; 3 & 8) 18 min. decorticated wheat flour; 4 & 9) 9 min. decorticated wheat flour; 5 & 10) whole wheat flour

TABLE XXIV

COOKED WHEAT COUSCOUS COLOR (AGTRON[1])

| Samples | Red Wheat 8W[2] | Red Wheat 14W[3] | White Wheat 8W[2] | White Wheat 14W[3] |
|---|---|---|---|---|
| Farina | 62.7 | 62.7 | 63.7 | 62.7 |
| Flour | 53.3 | 53.0 | 55.0 | 54.0 |
| 18 min. D[4] | 23.7 | 24.7 | 33.3 | 34.3 |
| 9 min. D[4] | 20.3 | 22.3 | 31.0 | 33.0 |
| 0 min. D[4] | 18.7 | 18.7 | 25.7 | 26.7 |
| Commercial Couscous | | | | |
| Sipa | | 51.0 | | |
| Fantastic Foods | | 48.0 | | |

[1]0 = black, 100 = white

[2]Thru No. 8, over No. 14 wire screen

[3]Thru No. 14, over No. 18 wire screen

[4]Decortication


Fig. 14 Cooked Couscous Photograph: 1-5 made from Hard White Winter Wheat; 6-10 made from Hard Red Winter Wheat; 1 & 6) farina; 2 & 7) conventional mill flour; 3 & 8) 18 min. decorticated wheat flour; 4 & 9) 9 min. decorticated wheat flour; 5 & 10) whole wheat flour

TABLE XXV

SENSORY EVALUATION

Samples Found Acceptable

| Decortication Time (min.) | White Wheat | | | Red Wheat | | |
|---|---|---|---|---|---|---|
| | 18 | 9 | 0 | 18 | 9 | 0 |
| Dry | 100% | 86% | 29% | 0% | 0% | 0% |
| Cooked | 60 | 80 | 75 | 60 | 50 | 0 |

Cooked samples were more varied, but no panelist found the non-decorticated red wheat acceptable. Other reasons besides color may have affected their judgement; some comments indicated that texture rather than color was a major factor. Reasons given by the panelists were: the flavor was not acceptable; the sample is not considered to be couscous in their country (Algeria); not cooked enough; too dry; & taste floury.

# SUMMARY AND CONCLUSIONS

Two products were developed from Hard White Wheat. Both of these products could have potential in the market-place if there were an incentive to use them.

Hamburger bun control height could be maintained with the following material additions: 30% cracked wheat with 18% vital gluten, 40% flaked wheat with 10% vital gluten, 20% bran with 19% vital gluten, and whole wheat flour was replaced at 50% with 10% vital gluten addition. White-wheat buns made with these formulations were lighter in color than buns made with hard red wheat. Taste-test panelists found a significant taste difference between the red-wheat and white-wheat buns, but did not prefer one over the other.

Whole hard white wheat couscous measured with the agtron had the same color value as a HRW wheat decorticated 18 min. Taste panelists accustomed to eating durum semolina couscous found the white wheat couscous acceptable, but not the red wheat couscous. HWW wheat may provide an acceptable alternative to coarse grains such as sorghum and pearl millet for making couscous.

In both products, the color was lighter for white wheat when HRW & HWW were in the product in equal amounts. The taste was also more bland for the white wheat products.

Further work could be done in identifying the flavor and color compounds in white wheat bran which are different from these in red wheat bran. Red whole wheat foods have a brown

color whereas white whole wheat has a yellowish color. Although not attempted in this work, the yellow color has been demonstrated to be substantially reduced by bleaching the flour. Further studies could focus on bleaching the whole hard white wheat flour to reduce this yellow color.

HWW wheat appears to have a great potential in any product that would include whole wheat because of its more bland flavor and lighter color compared to HRW. It could be appealing to consumers wanting the nutritional fiber advantages, but who do not like the astringent taste of whole wheat products. Ultimately, for HWW wheat to succeed in the market-place there will have to be a price incentive for it to be grown, stored, milled, and sold separately from HRW.

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**HARD WHITE WINTER WHEAT**

**HAMBURGER BUNS AND COUSCOUS**

**PRODUCT DEVELOPMENT**

by

Cristina E. Lang

B.S., Nebraska Wesleyan University, 1982

AN ABSTRACT OF A THESIS

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MASTER OF SCIENCE

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ABSTRACT

Hard White Winter (HWW) wheat is beginning to be grown in the U. S., including Kansas. Most prior research has been on the wheat's agronomic properties, so two products were developed from HWW-Hamburger Buns and Couscous (a North African product) to compare its performance with Hard Red Winter (HRW) wheat.

A high fiber whole white wheat hamburger bun, lighter in color and more bland in flavor than one from HRW might have wide consumer acceptability. White bran, as well as cracked and flaked wheats, were also added to create the effect of whole wheat without seriously affecting the color. Comparing red wheat with white wheat buns, the white ones had higher Agtron values (lighter color) except for cracked wheat, which was equal. In a triangle test under red light, taste panelists easily differentiated red-wheat from white-wheat buns.

Couscous is usually made from durum wheat semolina, but grains such as sorghum and pearl millet are sometimes used. Color is an important factor in couscous, but whole wheat may provide economic and nutritional advantages.

An objective was to develop an acceptable couscous made from whole hard white wheat flour. A laboratory scale method was developed, and the resulting couscous was compared with that made from hard wheat farina and with durum semolina for absorbance, particle size, color, and taste.

Whole wheat couscous made from HWW wheat was lighter in color than whole wheat couscous made from HRW wheat. Whole wheat couscous was noticeably different in color and taste than that made from conventional wheat flour or durum semolina, but it may be an acceptable alternative to couscous made from coarse grains such as sorghum and pearl millet.

Both hamburger buns and couscous made from HWW wheat were lighter in color, and more bland in flavor than the HRW foods, and could be identified by taste panelists as different.